THE AQUATIC PLANT COMMUNITY OF CROOKED LAKE, ADAMS COUNTY, WISCONSIN NOVEMBER 2010

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Executive Summary

A study of the aquatic macrophytes (plants) in Crooked Lake was conducted during the summers of 2009 and 2010 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR). An aquatic plant surveys was conducted by staff of Adams County Land and Water Conservation in 2009 as a follow-up to the first quantitative vegetation study of Crooked Lake completed in 2005. Two aquatic surveys were done during the summer of 2009: one by the transect method, in order to match changes from the 2005 results, and one by the point intercept (PI) method to establish a new baseline for further aquatic plant surveys. The only survey completed in 2010 used the PI method

Crooked Lake is a 58.8-acre seepage lake in southeast Adams County, Wisconsin. Crooked Lake has a maximum depth of 56 feet and a mean depth of 11.2 feet. Crooked Lake is a designated outstanding waterbody with a forested wetland corridor on the western/southwestern part of the lake that extends over 500 feet inland from the ordinary high water mark of the lake. As in the case in all seepage lakes, the water level on Crooked Lake fluctuates naturally with the underground water table. Most of the shore is undisturbed by development and has been divided into several critical habitat areas.

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicate that Crooked Lake is a borderline oligotrophic/mesotrophic lake with good-to-very good water quality. This trophic state should favor moderate plant growth and occasional localized summer algal blooms.

Of the 59 species found in Crooked Lake during the 2009 and 2010 surveys, 28 were emergent species, 6 were floating-leaf species, 3 were free-floating species and 22 were submergent species. One endangered species was found: *Eleocharis quadrangulata*. One species of special concern was also present: *Utricularia gemniscapa.* Aquatic mosses and freshwater sponges were also found at several points. Three invasive species were found: *Myriophyllum spicatum* (Eurasian watermilfoil); *Phalaris arundinacea* (Reed canarygrass); and *Potamogeton crispus* (Curly-leaf pondweed).

The same three aquatic species were the most frequently-occurring plants under both survey types. *Chara* spp. was the most frequently-occurring species in Crooked Lake in all the 2009 and 2010 surveys. Other frequently occurring plants were *Nymphaea odorata* and *Myriophyllum sibiricum*, although they might be second or third most frequently-occurring, depending on the particular survey.

From both surveys, *Chara* spp. was also the species with the highest mean density in Crooked Lake. The next two plants with the highest mean density were *Nymphaea odorata* and *Myriophyllum sibiricum*, but these far below the density of *Chara* sp. *Chara* spp. also had the highest "mean density where present". In the 2010 PI survey, it had a more than average density of growth.

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community. Based on the Dominance Value, *Chara* spp. was the dominant aquatic plant species in Crooked Lake in all three surveys. *Nymphaea odorata* was sub-dominant in the transect method. No species was sub-dominant using the PI method.

The Simpson's Diversity Index (SI) for the transect 2009 survey was .93. For the PI surveys, it was.85 in 2009 and .81 in 2010. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). These place Crooked Lake in the upper quartile for diversity for all the lakes in Wisconsin and for the North Central Hardwoods Region. The SI score of .93 places Crooked Lake in the excellent category for lakes in Wisconsin and in the North Central Hardwoods Region (Nichols, et al, 2000).

The Aquatic Macrophyte Community Index (AMCI) for Crooked Lake is 62 (based on all three surveys). This value is above average for lakes in the North Central Hardwoods Region and Wisconsin and indicates that the aquatic plant community in Crooked Lake is of above average quality (Nichols, et al, 2000). The PI surveys had a higher frequency occurrence rate for submersed species, since their results had fewer emergent plants and fewer rooting floating-leaf plants than the transect survey. Since the AMCI does not include emergent plants in its table, the transect method results yielded a slightly lower AMCI score in the frequency of submersed plants category. However, the transect method resulted in a higher Simpson's Diversity Index, so the score for that component was higher in the transect method.

MANAGEMENT RECOMMENDATIONS

1) All lake residents should practice best management on their lake properties. Crooked Lake is borderline between oligotrophic and mesotrophic. A small increase in nutrients could push the lake into another trophic state, resulting in noticeably worse water quality. Conversely, reducing nutrients could have a noticeable favorable impact on water quality.
    - Keep septic systems cleaned and in proper condition;
    - Use no lawn fertilizers;
    - Clean up pet wastes;

- No composting should be done near the water nor should yard wastes & clippings be allowed to enter the lake (Do not compost near the water or allow yard wastes and clippings to enter the lake)

2) Residents should continue involvement in the Citizen Lake Monitoring Program, monitoring water quality to track seasonal and year-to-year changes.

3) Now that most of the lake is designated as critical habitat areas, a map of these areas should be posted at the public boat ramp with a sign encouraging avoidance of motorboat disturbance to these areas. Landowners on the lake should watch for disturbance of these areas and report any violations. These areas are very important for habitat, the high value aquatic plant community, maintaining the positive water quality and for preserving endangered and rare species.

4) The Crooked Lake Association should continue working with the Adams County Land & Water Conservation Department in the ongoing Eurasian Watermilfoil removal project and also start hand-removing Curly-Leaf Pondweed. These exotic species should be controlled and maybe eliminated before it spreads. Initially, hand-pulling could be attempted. However, considering the shallow areas of Crooked Lake are several feet deep in marl muck, spot chemical treatments may be required for control in these areas.

5) A harvesting and/or herbicide map must be developed to identify the corridors to be cleared for boating access around the lake.

6) Lake residents should protect natural shoreline around Crooked Lake. Cultivated lawn covers 6% of the shore. In most instances on Crooked Lake, there are already buffer areas even at the disturbed sites. An increase in the depth of these buffer areas is recommended to 35 feet landward from shore.

7) Steps should be taken to encourage reduction of boat speed in the shallow water areas to reduce disturbance to plants.

8) All lake users should protect the aquatic plant community in Crooked Lake. The standing-water emergent community, floating-leaf community and submergent plant community are all unique plant communities. Each of these plant communities provides their own benefits for fish and wildlife habitat and

water quality protection.

9) An aquatic plant survey should be repeated in 3 to 5 years in order to continue to track any changes in the community and the lake's overall health.

10) The Crooked Lake Association should consider approaching the two landowners who own much of the waterfront property on the east and west sides of the lake and see if those landowners would be interested in conservation easements. If so, the Crooked Lake Association could apply for a WDNR grant to gain these easements. These easements would help ensure that the threatened habitats on Crooked Lake remain undisturbed.

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Crooked Lake was conducted during the summer of 2009 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and Adams County Land and Water Conservation. These were a follow-up to the first quantitative vegetation study of Crooked Lake completed in 2005. Two aquatic surveys were done during the summer of 2009: one by the transect method, in order to match changes from the 2005 results, and one by the point intercept method to establish a new baseline for further aquatic plant surveys. Another PI surveys was completed in 2010 by staff of the WDNR.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation in the lake and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life - the beginning of the food chain. Aquatic plants and algae provide food and oxygen for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants provide habitat, improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The present study will provide ongoing information that is important for effective management of the lake, including fish habitat improvement, protection of sensitive habitat, aquatic plant management and water quality protection. It will also allow tracking of any significant changes in the aquatic plant community that may indicate changes in the lake's overall health.

Background and History: Crooked Lake is a 58.8-acre seepage lake in southeast Adams County, Wisconsin. Crooked Lake has a maximum depth of 56 feet and a mean depth of 11.2 feet. Crooked Lake is a designated outstanding waterbody with a forested wetland corridor on the western/southwestern part of the lake that extends over 500 feet inland from the ordinary high water mark of the lake. As in the case in all seepage lakes, the water level on Crooked Lake fluctuates naturally with the underground water table.

Most of the shore is undisturbed by development and has been divided into several critical habitat areas. Several types of wetlands are found along this shoreline: shallow marsh; deep marsh; sedge meadow; shrub-carr; conifer bog; and tamarack bog. Large woody cover is common for habitat.

Eurasian Watermilfoil (*Myriophyllum sibiricum)* was found in Crooked Lake during the 2005 survey, at the boat landing and along the shoreline immediately across from the boat landing. This is where fragments from the boat landing likely drifted. The Crooked Lake Association and Adams County Land and Water Conservation Department have been regularly monitoring the lake for further spread of Eurasian Watermilfoil. Removal by handpulling has also been ongoing.

The Point Intercept Survey in 2009 found the exotic *Potamogeton crispus* (Curly-Leaf Pondweed) at one point in 14 feet of water. No other reports of this plant's presence have been made. It was not found during the 2010 PI survey.

There may have been herbicide treatments in the past for aquatic plant control, but no record has been located for such. Requests for treatment of aquatic plants with arsenic around a swim raft were made in 1948, but no permit applications or treatment records exist; a permit application for chemical treatment of aquatic plants was approved in 1986, but no record exists for chemical treatment; an incomplete permit application for chemical treatment was returned to the riparian in 1989 and no completed application was submitted. The status of these treatment requests is uncertain.

In 2005, the Crooked Lake Association purchased a hand-held weed cutter that is mechanized by attachment to a boat motor. The WDNR issued the lake association a permit to use this cutter to keep a channel open between the two parts of the lake. No other mechanical harvesting has been done on this lake.

Much of Crooked Lake was designated as critical habitat area by the Wisconsin Department of Natural Resources. Wisconsin Rule 107.05(3)(i)(I) defines "critical habitat areas" as: "areas of aquatic vegetation identified by the department as offering critical or unique fish & wildlife habitat or offering water quality or erosion control benefits to the body of water." Thus, these sites are essential to support the wildlife and fish communities. They also provide mechanisms for protecting water quality within the lake, often containing high-quality plant beds. Finally, sensitive

areas often can provide the peace, serenity and beauty that draw many people to lakes in the first place. The areas so designated on Crooked Lake are shown in Figure 1 and are briefly described below.

FIGURE 1: CROOKED LAKE CRITICAL HABITAT AREAS

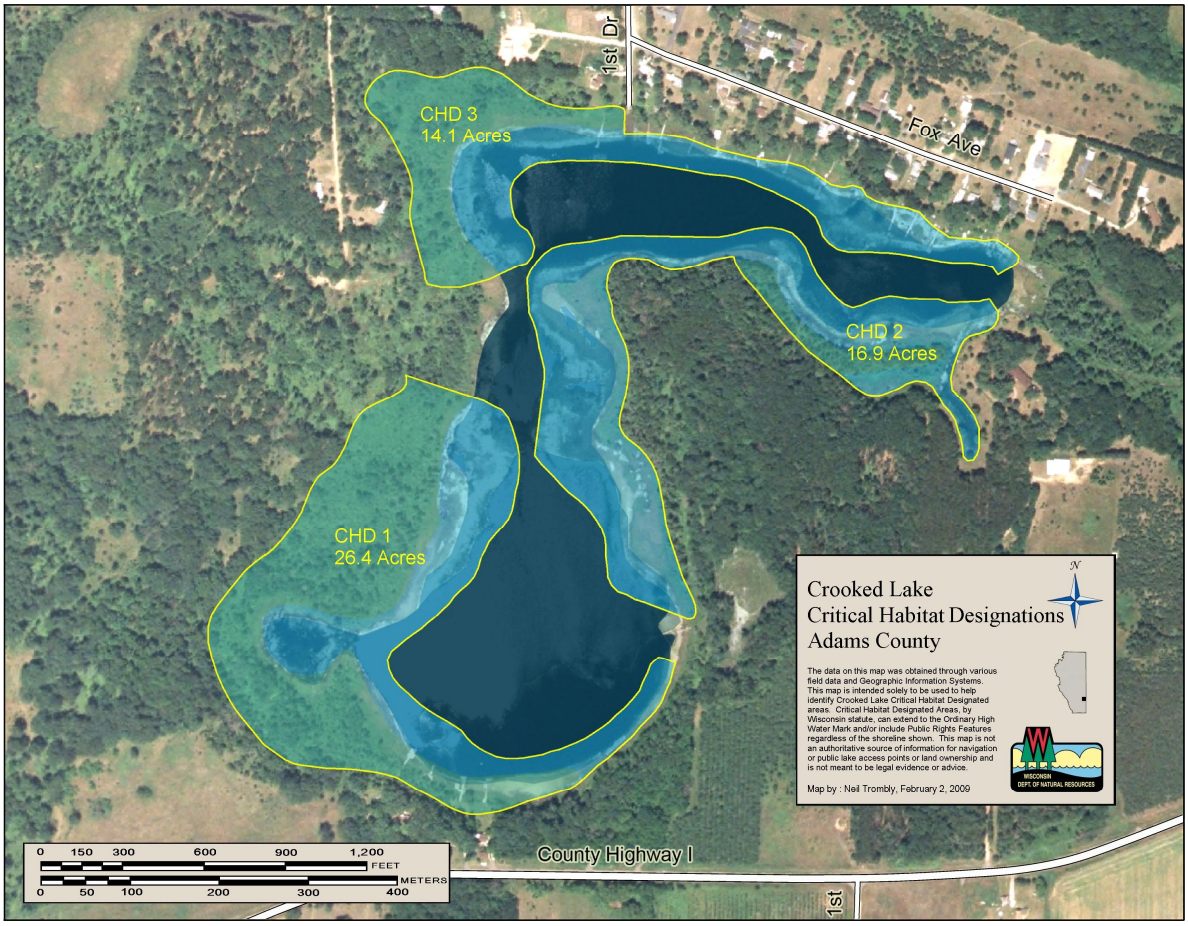


Figure 2. Critical Habitat Designated Areas

<u>Area CHD1:</u> This area extends along approximately 4200 feet of the shoreline. Sediment includes marl, muck, peat, sand, silt and mixtures thereof. 24% of the shore is wooded; 27% has shrubs; 49% is native herbaceous cover. Several types of wetlands are found along this shoreline: shallow marsh; deep marsh; sedge meadow; shrub-carr; and tamarack bog. Large woody cover is common for habitat. One threatened aquatic species, *Eleocharis quadrangulata*, was found along this sensitive

area. Maximum rooting depth of aquatic vegetation in CR1 was 19 feet. Seventeen types of aquatic plants, plus aquatic moss, were found in this sensitive area: three emergents; four floating-leaf or floating-free plants; ten submergent plants. No exotic invasive plants were found in this area. Most of the aquatic vegetation in this area has multiple uses for fish and wildlife. Because this site provides all three structural types of vegetation, the community has a diversity of structure and species that supports even more diversity of fish and wildlife.

FIGURE 2: SEDGE MEADOW IN CHD1 AT CROOKED LAKE

Area CHD2: This area extends along approximately 2900 feet of the shoreline. Sediment includes marl, peat, silt and mixtures thereof. 40% of the shore is wooded; 10% has shrubs; 50% is native herbaceous cover. Sedge meadow and tamarack bog wetlands are found along this shoreline. Large woody cover is abundant for habitat.

Maximum rooting depth in CR2 was 18 feet. No threatened or endangered species were found in this area. One exotic invasive, *Myriophyllum spicatum* (Eurasian watermilfoil), was found in this area. Of the eighteen aquatic plant species found here, three were emergent species; two were floating-leaf rooted plants; thirteen were submergent species. Most of these plants are used by wildlife and fish for multiple purposes. Because this site provides all three structural types of vegetation, the community has a diversity of structure and species that supports even more diversity of fish and wildlife.

FIGURE 3: TAMARACK BOG IN CHD2 AT CROOKED LAKE

Area CHD3: This area extends along approximately 3300 feet of the shoreline. Sediment includes marl, muck, peat, sand, silt and mixtures thereof. 7% of the shore is wooded; 20% has shrubs; 57% is native herbaceous cover—the remaining 21% is

cultivated lawn. This sensitive area includes the most developed area of Crooked Lake. However, there are areas of wetlands: shallow marsh; sedge meadow; conifer swamp. Large woody cover is present, but not as much as in the other two sensitive areas. Most development in this area has been carried out so as to preserve habitat and minimize negative human impact. Maximum rooting depth in CR3 was 18 feet. No threatened or endangered species were found in this area. One exotic invasive, *Myriophyllum spicatum* (Eurasian watermilfoil), was found in this area. 45% of the area has filamentous algae, especially near the shores. Of the seventeen aquatic plant species found here, four were emergent; two were floating-leaf rooted plants; and ten were submergent species. Most of these plants are used by wildlife and fish for multiple purposes. Because this site provides all three structural types of vegetation, the community has a diversity of structure and species that supports even more diversity of fish and wildlife.

FIGURE 4: DEVELOPED AREA IN CHD3 AT CROOKED LAKE

II.METHODS

Field Methods

The transect study design was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines. The shoreline was divided into 16 equal segments, and a transect line, perpendicular to the shoreline, was randomly placed within each segment, using a random numbers table.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a long-handled steel thatching rake or a

thatching rake on a rope, four rake samples were taken at each sampling site, one from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5), the number of rake samples on which it was present at each sampling site.

A rating of 1= the species was present on one rake sample at that site;
A rating of 2 = the species was present on two rake samples at that site;
A rating of 3 = it was present on three rake samples;
A rating of 4 = it was present on all four rake samples;
A rating of 5 = it was abundant on all four rake samples.

Visual inspection and periodic samples were taken between transect lines to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on each side of the transect intercept with the shore and 30 feet landward, was evaluated. The percent cover of each land use category within this 100' x 30' rectangle was visually estimated and recorded on a data sheet.

The second method used was the Point Intercept Method. This method involves calculating the surface area of a lake and dividing it (using a formula developed by the WDNR) into a grid of several points, always placed at the same interval from the next one(s). These points are related to a particular latitude and longitude reading. At each geographic point, the depth is noted and one rake is taken, with a score given between 1 and 3 to each species on the rake.

A rating of 1 = a small amount present on the rake;

A rating of 2 = moderate amount present on the rake;

A rating of 3 = large amount present on the rake.

A visual inspection was done between points to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording plants found.

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites). Relative frequency was calculated (number of occurrences of a species/sum of all species occurrences) .The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites). Relative density was calculated (sum of a species density/sum of all plant densities). "Mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred). The relative frequency and relative density of each species were summed to obtain a dominance value for each species. Species diversity was measured by Simpson's Diversity Index.

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols (Nichols, et al., 2000) was applied to Crooked Lake. Measures for each of seven categories that characterize a plant community are converted to values between 0 and 10 and summed to measure the quality of the plant community.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant

community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for all species found in the lake. The Floristic Quality Index is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae, water clarity and water hardness) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also impact the aquatic plant community.

WATER QUALITY - The trophic state of a lake is a classification of its water quality. Phosphorus concentration, chlorophyll concentration and water clarity data are collected and combined to determine the trophic state.

- Eutrophic lakes are high in nutrients and support a large biomass.
- Oligotrophic lakes are low in nutrients and support limited plant growth and smaller populations of fish.
- Mesotrophic lakes have intermediate levels of nutrients and biomass.

Nutrients

Phosphorus is a limiting nutrient in many Wisconsin lakes, including Crooked Lake, and is measured as an indication of nutrient enrichment in a lake. Increases in

phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth. The 2004-2010 Mean Summer (May through September) Phosphorus concentration in Crooked Lake was 15.9 micrograms/liter. This concentration of phosphorus in Crooked Lake is indicative of a mesotrophic lake (Figure 5).

Algae

Chlorophyll-a concentrations provide a measure of the amount of algae in lake water. Algae are natural and essential in lakes, but high algae populations can increase turbidity and reduce the light available for plant growth. The 2004-2010 Mean summer chlorophyll-a concentration in Crooked Lake was 3.7 micrograms/liter, in the oligotrophic range for chlorophyll-a levels.

Water Clarity

Water clarity is a critical factor for aquatic plants, because if they don't get more than 2% of surface illumination, they won't survive (Chambers and Kalff 1985, Duarte et. al. 1986, Kampa 1994). Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity is measured with a Secchi disc that shows the combined effect of turbidity and color The 2004-2010 Mean Summer Secchi Disc clarity in Crooked Lake was 12.7 feet. Water clarity indicates that Crooked Lake was an oligotrophic lake with very good water clarity.

Figure 5. Trophic Status of Crooked Lake

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.

Oligotrophic	Excellent	<1	<1	> 19
	Very Good	1-10	**1-5**	**8-19**
Mesotrophic	Good	**10-30**	5-10	6-8
	Fair	30-50	10-15	5-6
Eutrophic	Poor	50-150	15-30	3-4
Crooked Lake Growing Season 2004-2009	Good to Very Good	**15.9**	**3.7**	**12.7**

Overall Water Quality

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicate that Crooked Lake is a borderline oligotrophic/mesotrophic lake with good-to-very good water quality. This trophic state should favor moderate plant growth and occasional localized summer algal blooms.

Water quality was sampled in Crooked Lake by the DNR in 1992 and Adams County Land Conservation staff from 2004 through 2006, and picked up again in 2008 by citizen monitors, ongoing into 2010. The only other water quality sampling results located come from WDNR sampling done in 1992 on several occasions during the growing season. That year, the average growing season Secchi disc reading was 12.3 feet; the average total phosphorus level was 14 micrograms/liter; and the average chlorophyll-a level was 4.0 micrograms/liter. These results are in the same categories as the current averages: good (mesotrophic) for total phosphorus and very good for water clarity and chlorophyll-a (oliogotrophic).

Hardness

The hardness or mineral content of lake water also influences aquatic plant growth. The 2004-2006 hardness values in Crooked Lake ranged from of 201 to 208

milligrams/liter CaCO3. Lakes with hardness values greater than 180 mg/l CaCO3 are considered very hard water lakes. Hard water lakes tend to support more plant growth than soft water lakes (B.Shaw, et al, p.13). While marl (calcium carbonate) in a lake precipitates and falls to the lake bottom, some of the marl in hard water lakes often coats the external surfaces of submersed plants (C.E.Boyd, p. 112). Marl formations absorb phosphorus, reducing its overall concentration and decreasing algal growth (B. Shaw et al, p. 7).

LAKE MORPHOMETRY - The morphometry of a lake is an important factor in determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Crooked Lake has an irregularly-shaped basin with a gradually-sloped littoral zone and shallow depths in the northern three-quarters of the lake. The south quarter of the lake has more steeply-sloped littoral zone, dropping to over 50 feet in depth. Gradual slopes provide a more stable rooting base and broader area of shallow water that would favor plant growth.

SEDIMENT COMPOSITION – The most common sediment in Crooked Lake was peat, especially at depths greater than 5 feet (Figure 6). Marl/silt mixtures were common overall and were most common in the shallowest zone (0-1.5ft). Marl and mixtures of marl with other sediment types were also common in the 1.5-5ft depth zone.

Figure 6. Sediment Composition: Crooked Lake

Sediment Type		0-1.5' Depth	1.5-5' Depth	5-10' Depth	10-20’ Depth	Percent of all Sample Sites
Soft Sediments	Peat	12%	19%	38%	33%	25%
	Marl/Silt	31%	25%	12%	25%	23%
	Marl	12%	25%	19%	17%	18%
	Silt	6%	12%		17%	8%
	Marl/Peat		25%	19%	8%	8%
	Peat/Silt		12%	12%		7%
	Muck/Peat	19%				5%
Mixed Sediments	Sand/Marl	19%				5%

INFLUENCE OF SEDIMENT

Some plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility and texture of the sediment will determine the type and abundance of plant species that can survive in a location. The availability of mineral nutrients for growth is highest in sediments of intermediate density, such as silt, so these sediments are considered most favorable for plant growth (Barko and Smart 1986). Mineral availability in sediments such as sand is often considerably reduced.

Peat or peat mixtures sediments were found at 38% of the sites in Crooked Lake. Peat can be limiting for plant growth due to its flocculent nature. Although silt

alone was not commonly occurring in Crooked Lake (8%), it occurred in mixtures with peat or marl (30%), meaning that 38% of the sediment in Crooked Lake was favorable to plant growth. Since over 90% of the transect sites were vegetated in Crooked Lake, regardless of the sediment type, it doesn't appear that peat sediment was a limiting factor in determining plant distribution in Crooked Lake.

Figure 7: Sediment Distribution in Crooked Lake

SHORELINE LAND USE

Land use can strongly impact the aquatic plant community and therefore the entire aquatic community. Land use can directly impact the plant community through increased erosion and sedimentation and increased run-off of nutrients, fertilizers and toxics applied to the land. These impacts occur in both rural and residential settings.

Native herbaceous plant cover was the most frequently encountered shoreline cover at the transect sites and had the highest mean coverage. Wooded and shrub cover also had high occurrences and coverage (Figure 8).

Figure 8. Shoreline Land Use - Crooked Lake, 2009

Cover Type		**Frequency of Occurrences at Transects**	**Mean % Coverage**
Natural Shoreline	Native Herbaceous	100%	45%
	Wooded	84%	25%
	Shrub	95%	21%
Total Natural			91%
Disturbed Shoreline	Cultivated Lawn	11%	5%
	Hard Structure	32%	4%
Total Disturbed			9%

Some type of natural shoreline (wooded, shrub, native herbaceous) was found at all of the sites, having a mean coverage of 91%. A type of disturbed shoreline, cultivated lawn covered 9% of the shore (Figure 9).

Figure 9: Comparison of 2005 Shore Results to 2009 Shore Results

	Occurrence Frequency		Coverage	Coverage
	2005	2009	2005	2009
Wooded	62.5%	84.2%	20.0%	25.0%
Herbaceous	100.0%	100.0%	53.4%	45.0%
Shrub	81.3%	94.7%	20.0%	20.8%
Lawn	12.5%	10.5%	6.6%	5.3%
Hard Structure		26.3%		1.8%
Pavement		5.3%		2.1%

Wooded shoreline has increased slightly due to changes in the development pattern at Crooked Lake. Since 2005, several homes were built along the northwest side of the lake. In clearing areas for shore access, some herbaceous cover was removed, replaced by small trees and shrubs. This has led to higher shore cover by shrubs and trees and a smaller coverage by herbaceous growth. The increase in pavement and hard structure is due to the installation of docks and raised wooden walkways for the new development, as well as paving of part of the public boat ramp area by the county parks department.

MACROPHYTE DATA

SPECIES PRESENT

Of the 59 species found in Crooked Lake during the 2009 and 2010 surveys, 28 were emergent species, 6 were floating-leaf species, 3 were free-floating species and 22 were submergent species (Figure 10). One endangered species was found:

Eleocharis quadrangulata. One species of special concern was also present: *Utricularia gemniscapa*. Aquatic mosses and freshwater sponges were also found at several points. Three invasive species were found: *Myriophyllum spicatum* (Eurasian watermilfoil); *Phalaris arundinacea* (Reed canarygrass); and *Potamogeton crispus* (Curly-leaf pondweed).

Filamentous algae were found at 19% of the transect sites, always in over 5 feet of water. Filamentous algae were found during the PI survey at 12% of the sample sites, in water ranging from 2 feet to 17 feet deep.

Figure 10: Crooked Lake Aquatic Plant Species, 2009-2010

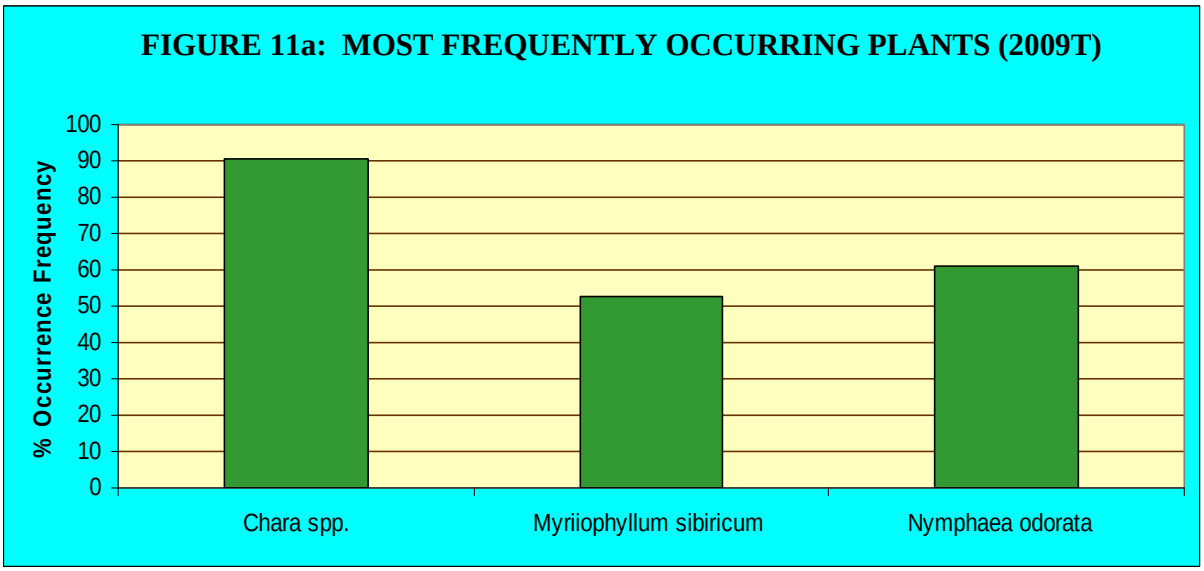
			Floating	Free-	
Scientific Name	**Common Name**	**Emergent**	**Leaf**	**Floating**	**Submergent**
Asclepias incarnata	Swamp Milkweed	x			
Aster lateriflorus	Calico Aster	x			
Aster linarifolius	Stiff Aster	x			
Bidens coronatus	Northern Tickseed	x			
Brasenia schreberi	Watershield		x		
Carex spp	Sedge	x			
Carex comosa	Bristly Sedge	x			
Carex stricta	Tussock Sedge	x			
Ceratophyllum demersum	Coontail				x
Cicuta bulbifera	Bulb-Bearing Water Hemlock	x			
Chara spp.	Muskgrass				x
Eleocharis palustris	Common Spikerush	x			
Elodea canadensis	Common Waterweed				x
Eupatorium perfoliatum	Boneset	x			
Eupatorium purpurea	Purple Joe Pye Weed	x			
Iris versicolor	Blue-Flag Iris	x			
Juncus spp	Rush	x			
Eleocharis quadrangulata	Square-Stem Spikerush	x			
Lobelia kalmii	Bog Lobelia	x			
Lemna minor	Lesser Duckweed			x	
Myriophyllum heterophyllum	Various-Leaf Milfoil				x
Myriophyllum sibiricum	Northern Milfoil				x
Myriophyllum spicatum	Eurasian Watermfilfoil				x
Najas flexilis	Bushy Pondweed				x
Najas guadelupensis	Southern Naiad				x
Nitella spp	Stonewort				x
Nuphar variegata	Yellow Pond Lily		x		

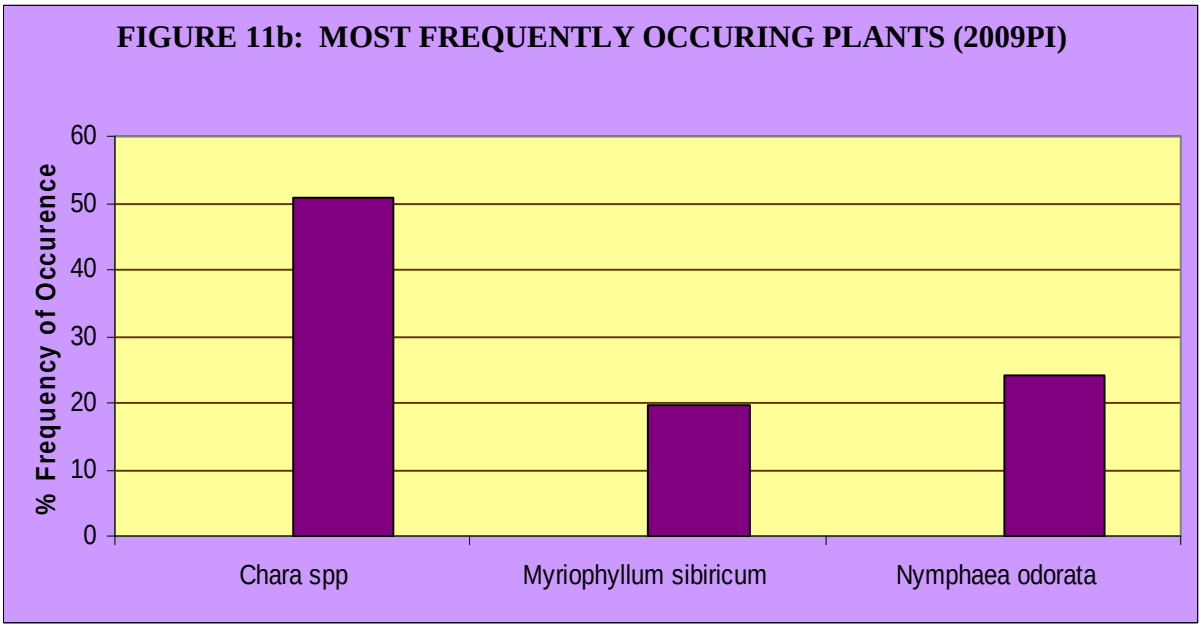
Nymphaea odorata	White Water Lily		x		
Onoclea sensibilis	Sensitive Fern	x			
Pedicularis lanceolata	Swamp Betony	x			
Phalaris arundinacea	Reed Canarygrass	x			
Polygonum amphibium	Water Smartweed		x		
Potamgoton crispus	Curly-Leaf Pondweed				x
Potamogeton foliosus	Leafy Pondweed				x
Potamogeton friesii	Fries' Pondweed				x
Potamogeton gramineus	Variable-Leaf Pondweed				x
Potamogeton illinoensis	Illinois Pondweed				x
Potamogeton nodosus	Floating-Leaf Pondweed				x
Potamogeton praelongus	White-Stemmed Pondweed				x
Potamogeton zosterformis	Flat Stemmed Pondweed				x
Rumex orbiculatus	Great Water Dock	x			
Salix spp	Willow	x			
Schoenoplectus acutus	Hard-Stemmed Bulrush	x			
Schoenoplectus tabernaemontani	Soft-Stemmed Bulrush	x			
Solidago canadensis	Canada Goldenrod	x			
Sparganium eurycarpum	Common Burreed	x			
Spiranthes romanzoffiana	Hooded Lady Tresses	x			
Spirodela polyrhiza	Greater Duckweed			x	
Stuckenia pectinata	Sago Pondweed				x
Typha latifolia	Wide-Leaved Cattail	x			
Utricularia geminscapa	Twin-Stemmed Bladderwort				x
Itricularia intermedia	Flat-Leaved Bladderwort				x
Utricularia minor	Lesser Bladderwort				x
Utricularia vulgaris	Greater Bladderwort				x
Wolffia columbiana	Common Watermeal			x	
Zosterella dubia	Water Stargrass				x

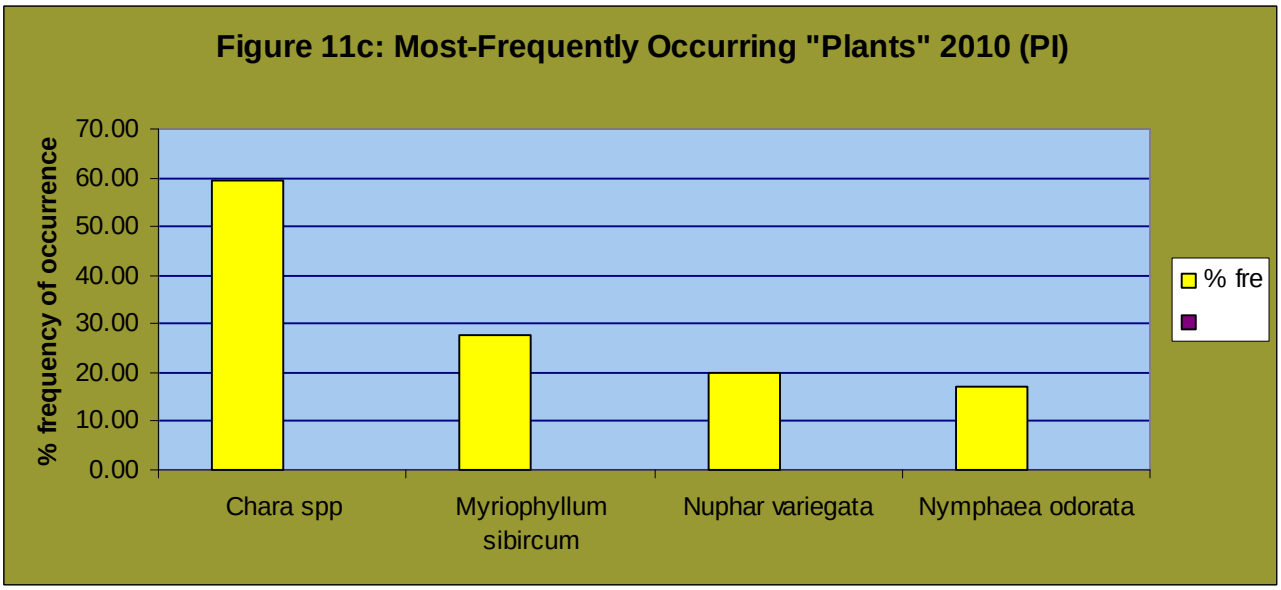
Half of the aquatic species found in the transect survey were emergents. 38% of the transect species were submersed aquatic species. The remaining 12% were split between free-floating plants such as *Lemna*, *Spirodela* and *Wolffia* and rooted floating leaf plants like *Nuphar*, *Nymphaea* and *Polygonum.* In the PI survey, 64% of the species plants were submersed; 18 % were emergent species; 7% were rooted floating-leaf plants; and 11% were free-floating plants.

FREQUENCY OF OCCURRENCE

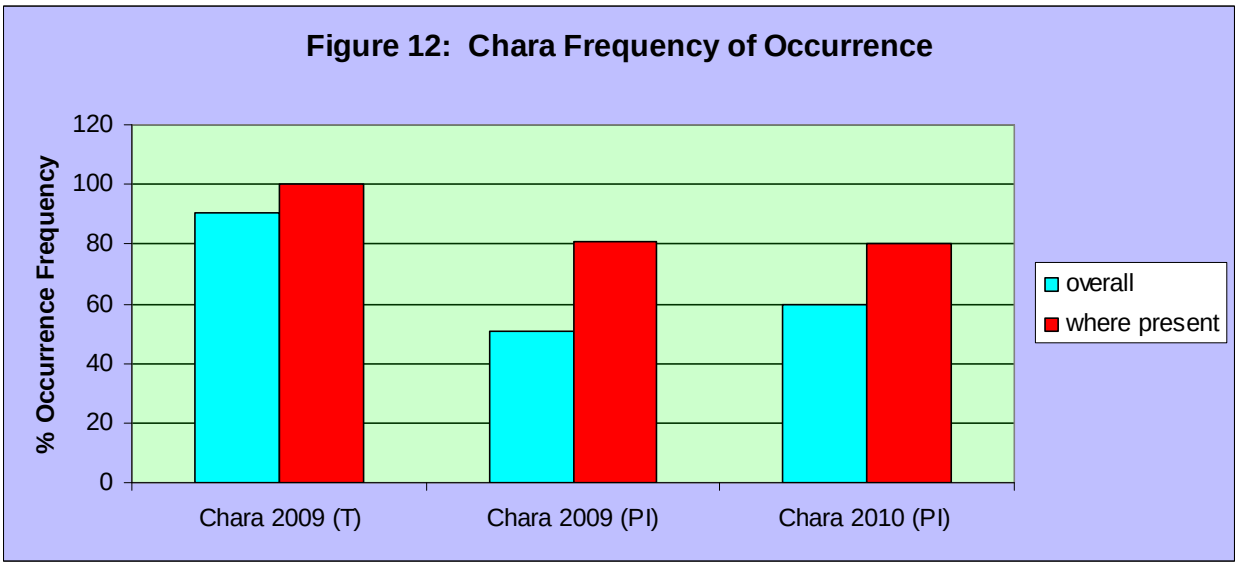
The same three aquatic species were the most frequently-occurring plants under all survey types. *Chara* spp. was the most frequently-occurring species in Crooked Lake in 2009 (Figures 11a & 11b). *Nymphaea odorata* and *Myriophyllum sibiricum* was the next most frequently-occurring plants then. The only change in 2010 was that *Nuphar variegata* scored close to *Nymphaea odorata* in occurrence frequency (Figure 11c).





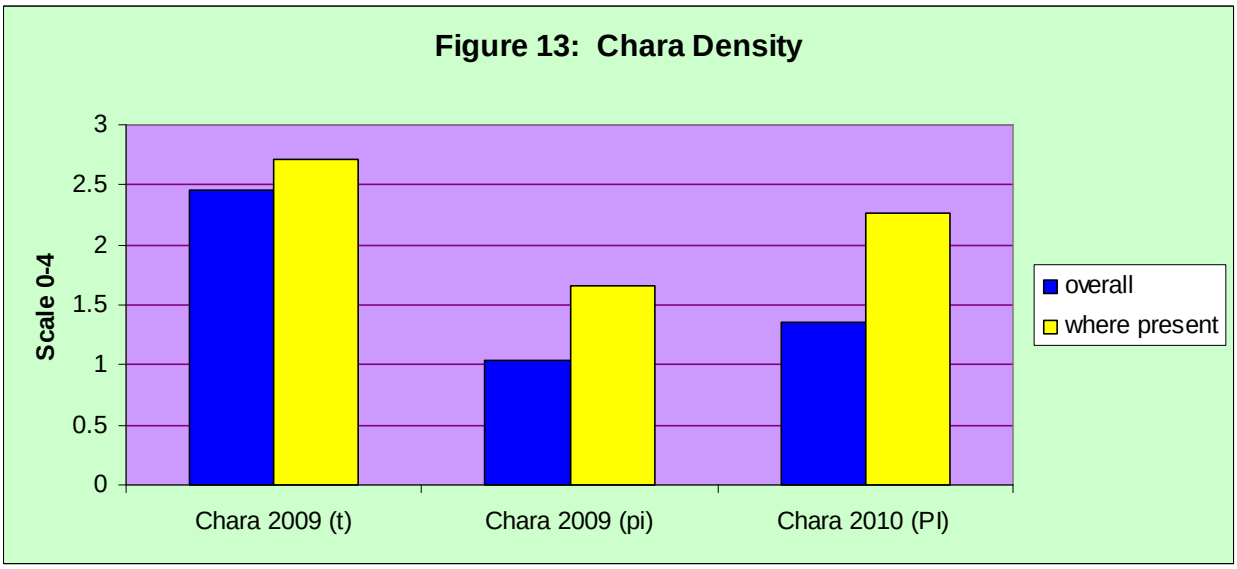


In the PI surveys, *Chara* spp had a frequency of occurrence where vegetated of 80% or more. In the 2009 transect survey, it had 100% occurrence frequency in vegetated sites on the lake.



DENSITY

From the 2009 surveys and 2010, *Chara* spp. was also the species with the highest mean density in Crooked Lake. The next two plants with the highest mean density were *Nymphaea odorata* and *Myriophyllum sibiricum.* *Chara* spp. also had the highest "mean density where present". The "mean density where present" indicates that, where *Chara* spp. occurred, it exhibited a dense growth form in Crooked Lake. In fact, from the 2009 transect survey and the 2010 PI survey, it was the only aquatic species that had a greater than average growth density. Under the 2009 PI survey, although *Chara* spp had the highest mean density where present, it did not occur in more than average growth density.



DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community. Based on the Dominance Value, *Chara* spp. was the dominant aquatic plant species in Crooked Lake (Figures 14a, 14b & 14c). *Nymphaea odorata* was sub-dominant in the transect method. No species was sub-dominant using the PI method.

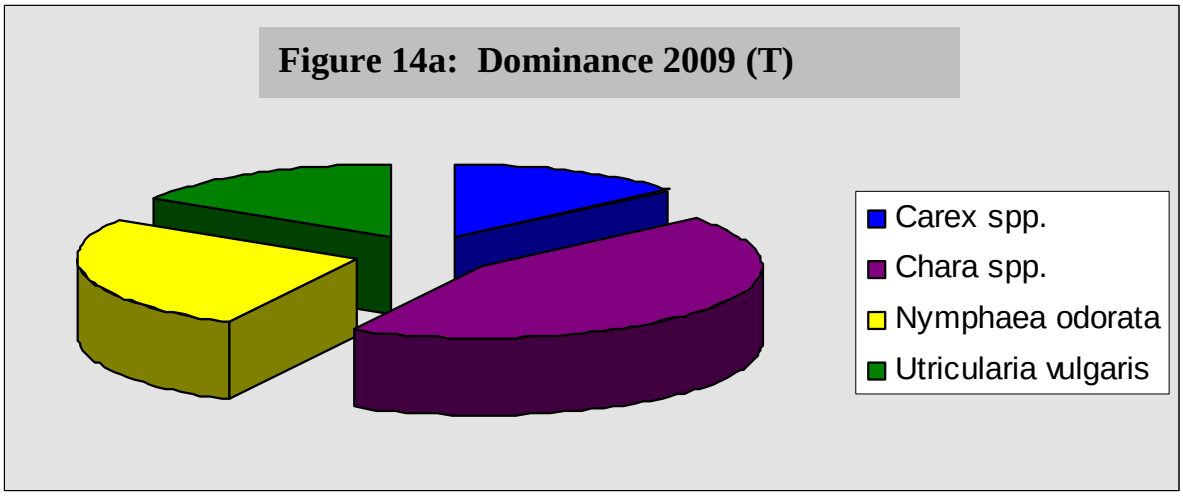


Figure 14b: Dominance 2009 (PI)

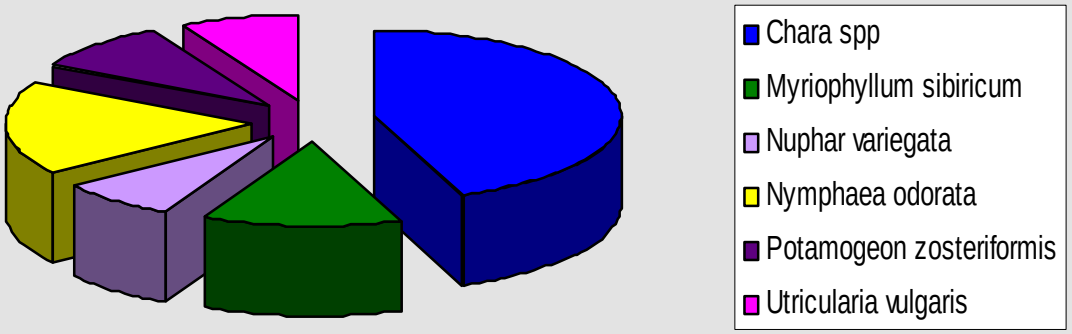
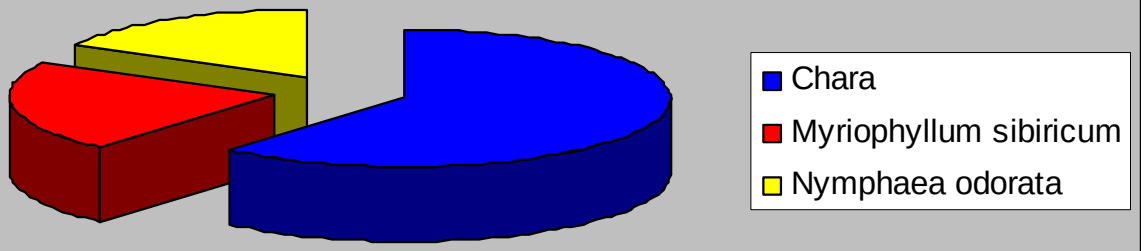


Figure 14c: Dominance Value 2010 (PI)



DISTRIBUTION

Aquatic plants occurred throughout the entire littoral zone of Crooked Lake, at all of the sampling sites to a maximum rooting depth of 17.5 feet for the transect method and 18 feet for the PI method in 2009. In 2009, the deepest rooted plant was *Myriophyllum sibiricum* at 18 foot in depth. The deepest rooted plant in 2010, *Potamogeton friesii,* was found at 16 feet. In 2009, *Chara* spp. was found at the greatest depth (20 feet) but is not a truly rooted species. In 2010, *Nitella* spp., an

unrooted macrophytic algae like *Chara* was found at 26 feet in depth. The dominant and common plant species were found throughout the lake.

Figures 15a, 154b, and 15c are maps showing the distribution of various aquatic plant types in Crooked Lake in 2009 under the transect method.

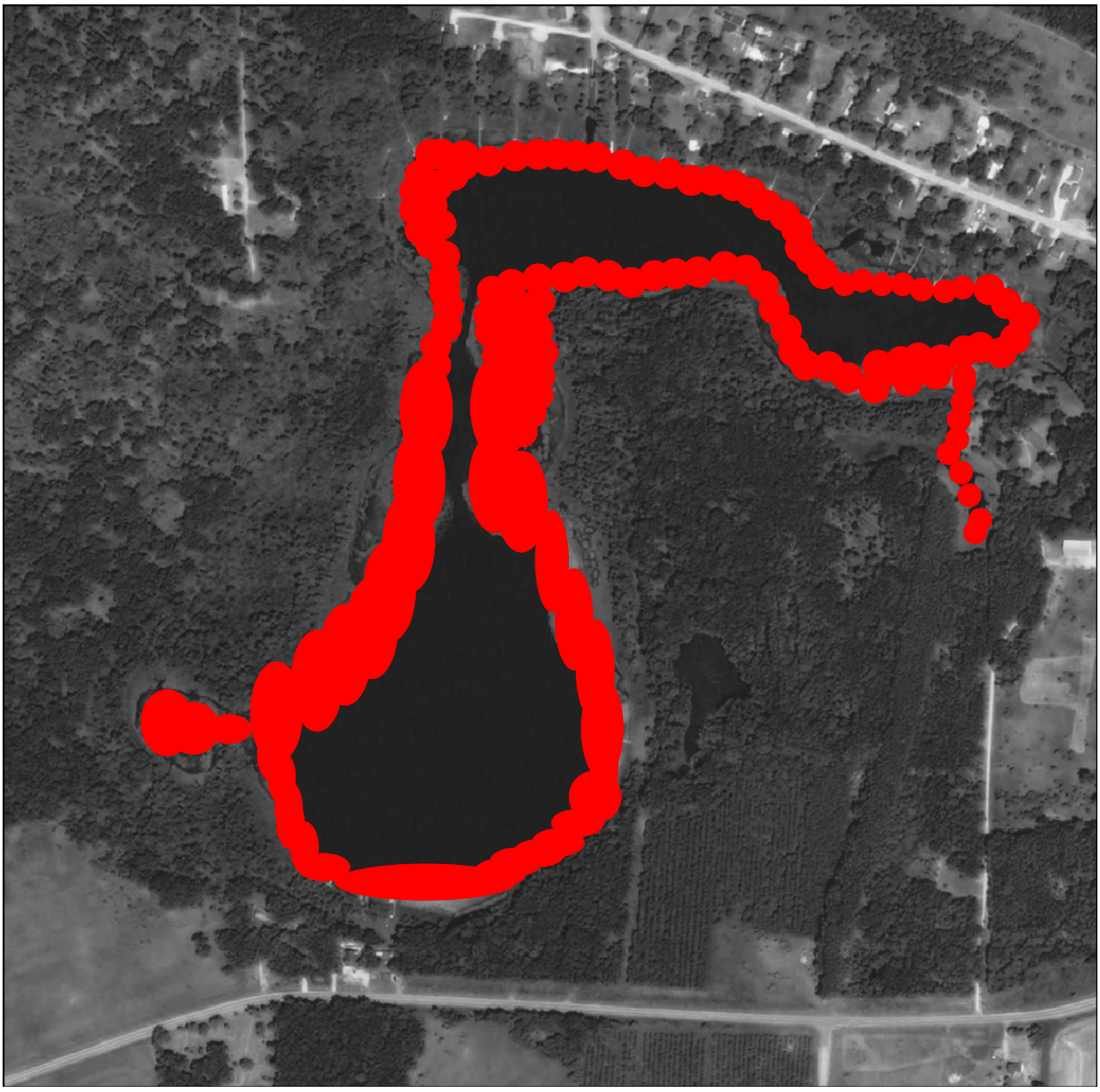


Figure 15a: Emergent Plant Locations (T) 2009 marked in red

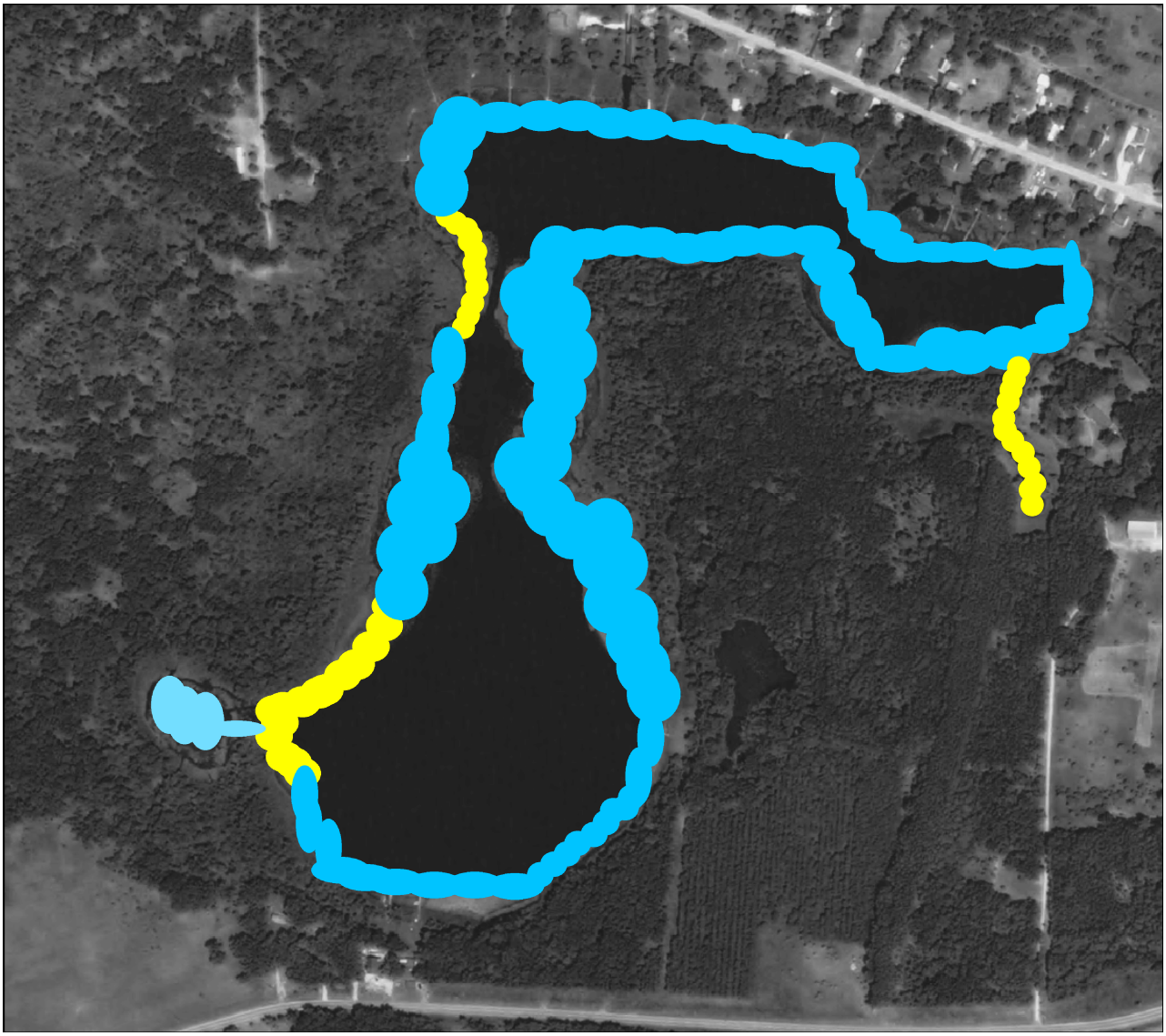


Figure 15b: Rooted Floating Leaf Plants (T) 2009 marked in blue—both Free-Floating & Rooted Floating Leaf Plants found in spots marked in yellow

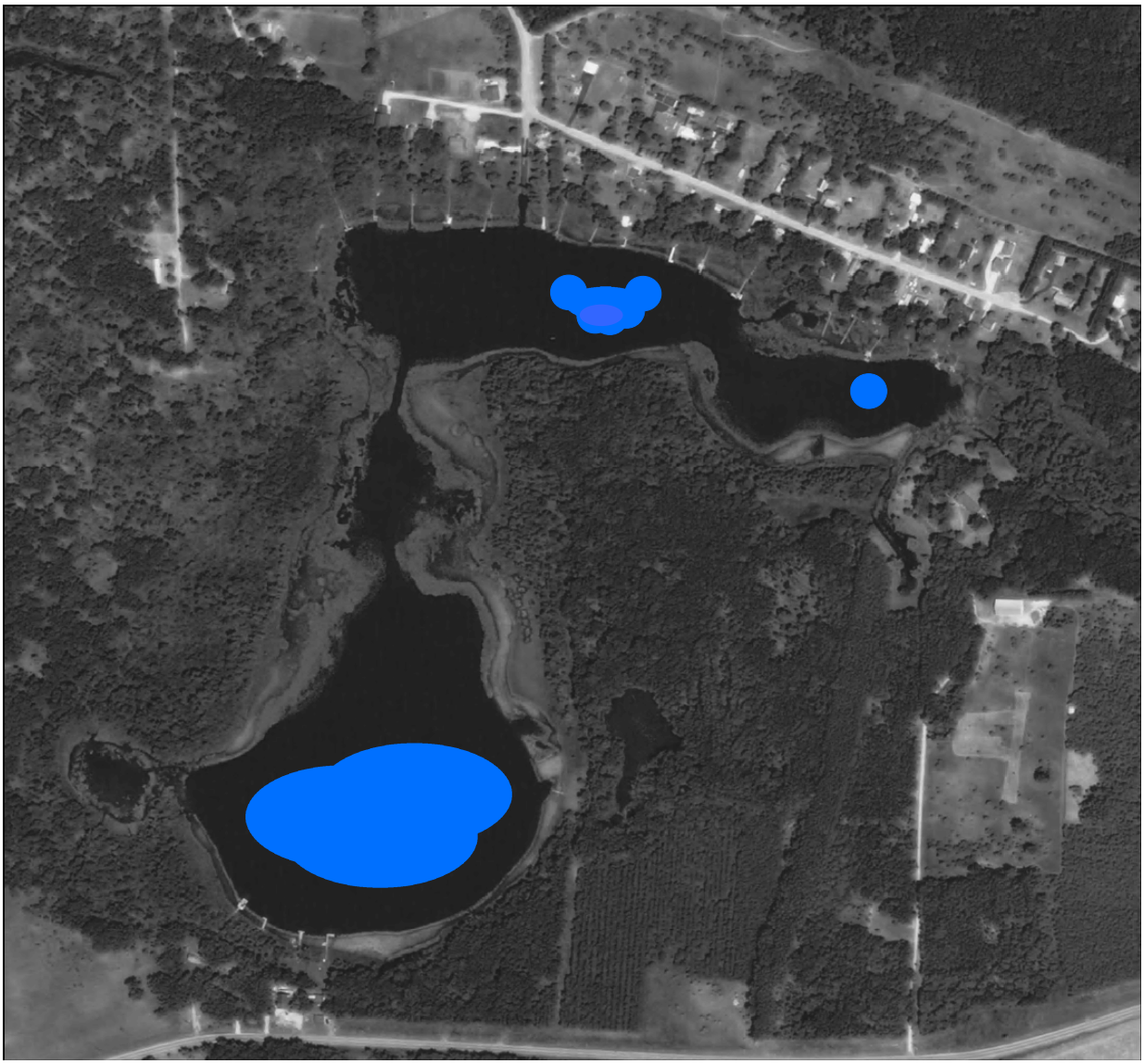


Figure 15c: SUBMERGENT PLANTS (T) 2009 LOCATED IN ALL AREAS EXCEPT THOSE MARKED IN BLUE

Figures 16a, 16b and 16c show aquatic plant species distribution results from the Point Intercept Survey in 2009.

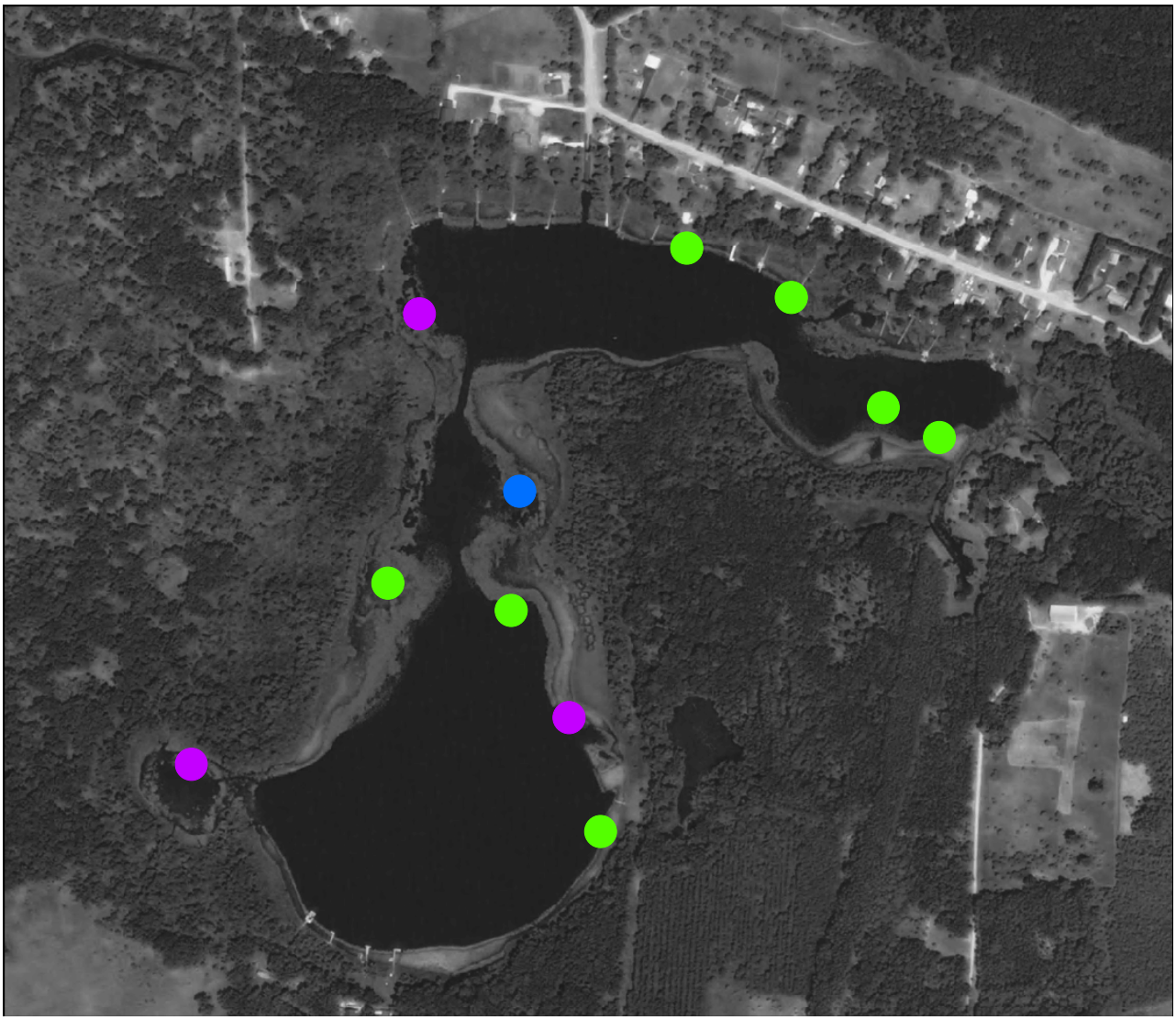


Figure 16a: POINT INTERCEPT MAP 2009 DISTRIBUTION FOR EMERGENT & FREE-FLOATING AQUATIC PLANTS

Emergent Plants Found 2009

Free-Floating Plants Found 2009

Both Emergent & Free-Floating Plants Found 2009

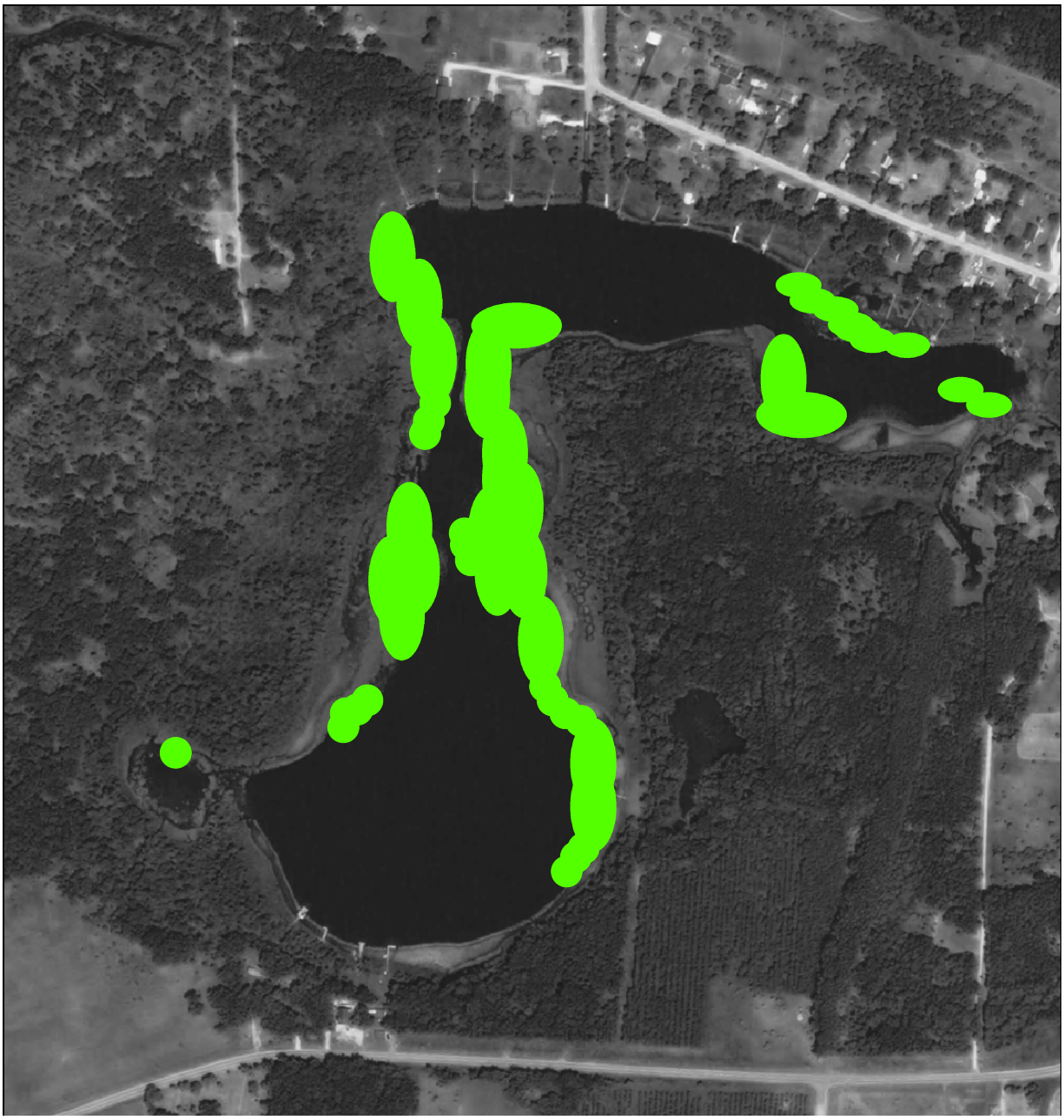


Figure 16b: POINT INTERCEPT MAP 2009
Rooted Floating Leaf Plants marked in green

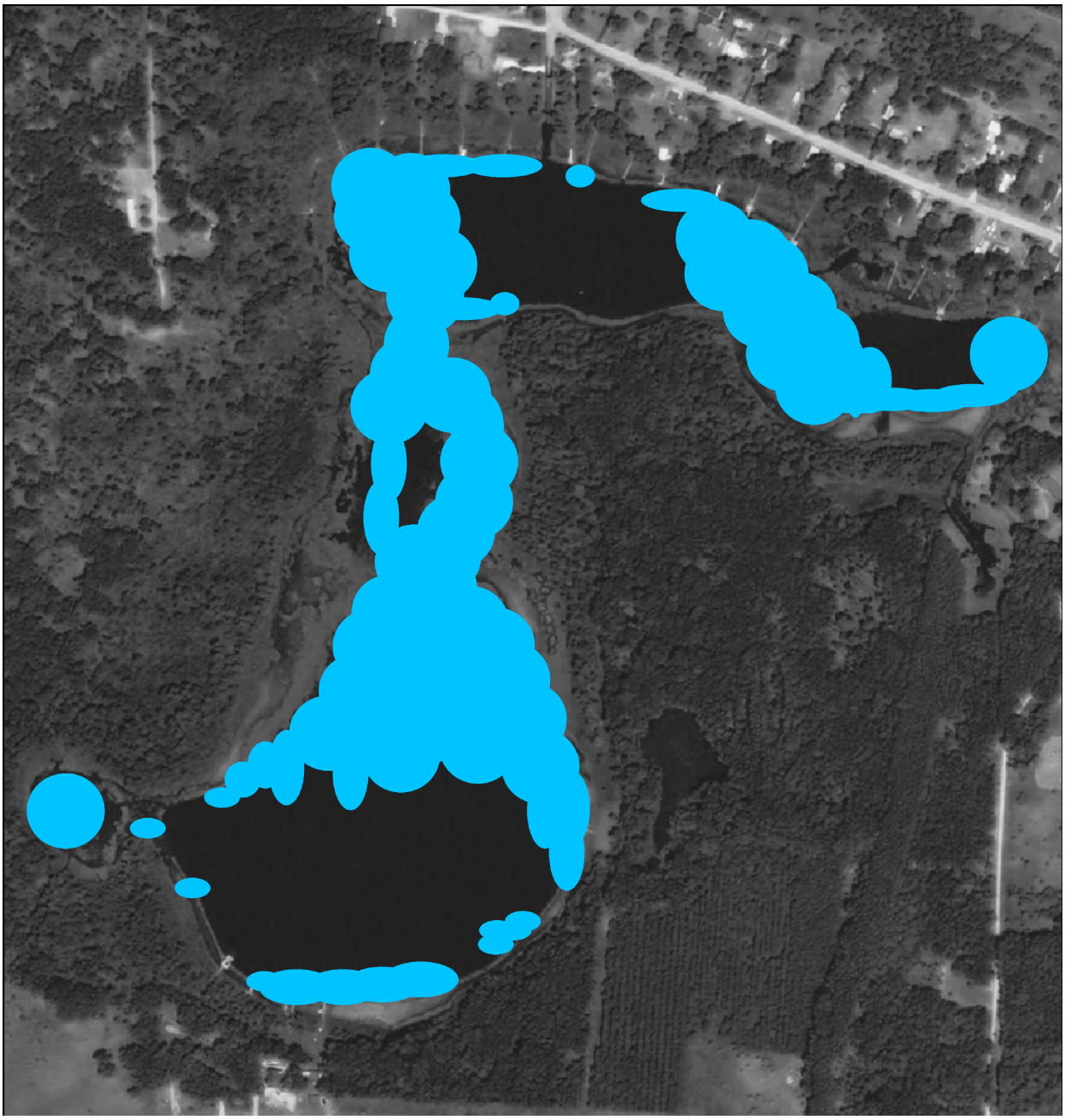


Figure 16c: POINT INTERCEPT MAP 2009—
SUBMERGED AQUATIC PLANTS marked in Blue

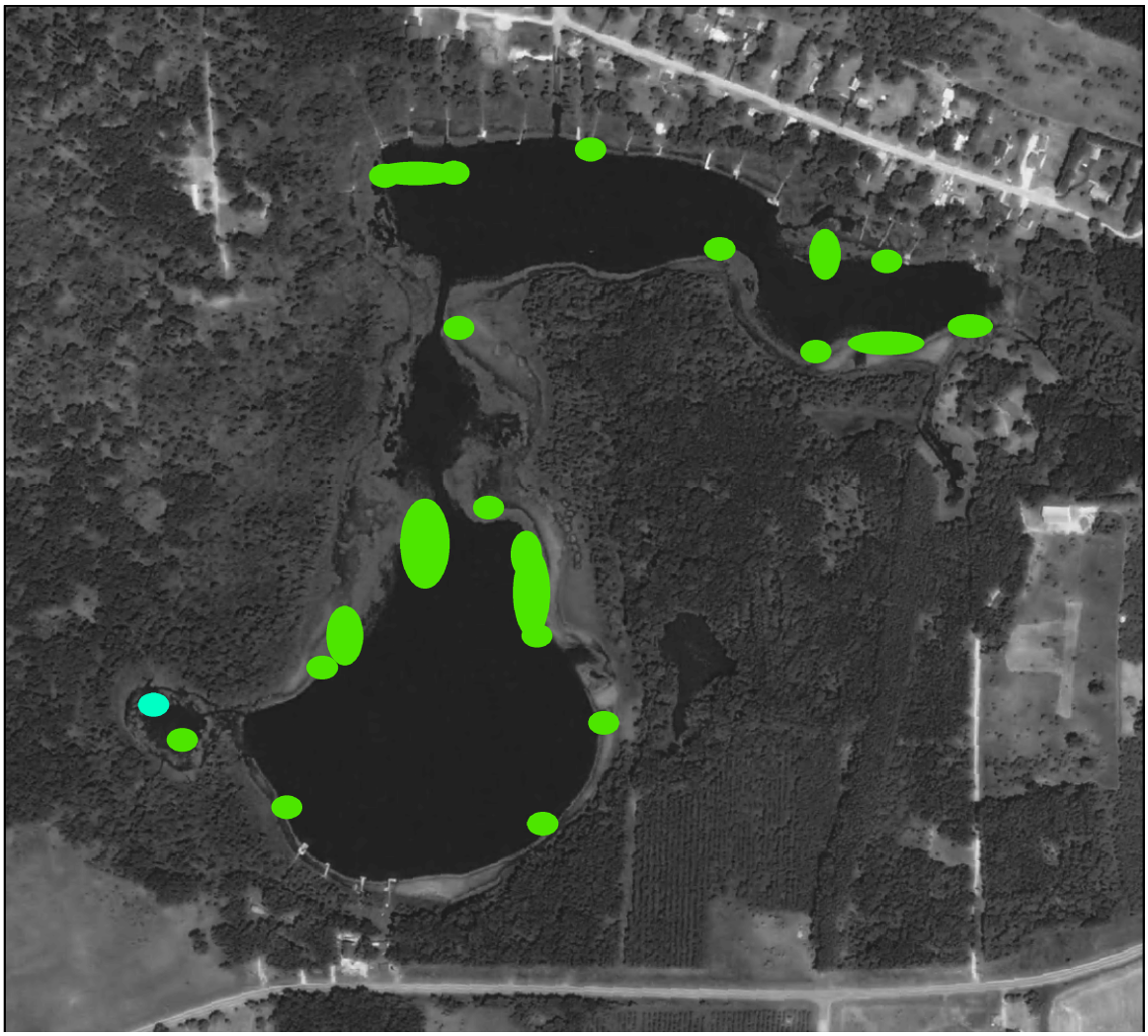


Figure 17a: Distribution of Free-Floating and Floating-Leaf Plants in Crooked Lake (2010PI)—Free-Floating shown in blue—Floating-Leaf shown in green

Figure 17b: Distribution of Submergent Plants in Crooked Lake 2010 (PI)—locations shown in yellow

Myriophyllum spicatum, Eurasian Watermilfoil, was found in Crooked Lake at the along the far northeast shore and around the boat landing on both sides. This has been monitored every year since the first discovery in 2005. So far, EWM has not been found in water more than 5 feet deep in Crooked Lake and has stayed along the north shore, especially along the northeast shore, which is the most developed area on the lake (see figure 18). The 2009 PI survey found Eurasian watermilfoil in only one spot and didn't find it at all in 2010. The 2009 transect survey found it at only three sites. Overall, it was first found in 2005 in two spots on the lake. It was verified and vouchered that year. It was found again in 2006 and 2007. None was found in 2008. It was found in 3 places in 2009, but not found in the 2010 survey. It has therefore been found in 4 of the last 6 years, always in small amounts. This pattern suggests that keeping an eye on its presence (or lack thereof) is very important.

In 2007, a survey was done to look for the native weevil known to damage Eurasian watermilfoil, *Euhrychiopsis lecontei*, in Crooked Lake. Adult and larval stages of the weevil were found, along with significant damage to stems that could be attributed to weevil presence. It is possible that this weevil is contributing to the continued low presence of Eurasian watermilfoil in Crooked Lake. Studies suggest that the number of these weevils is positively correlated with natural shoreline (Jester et al., 2000), since they overwinter in leaf litter near shore (Newman et al, 2001). Crooked Lake has a great deal of natural shoreline, suggesting that it is an appropriate habitat for these weevils.

Potamogeton crispus, Curly-Leaf Pondweed, was found during the PI survey at one spot in 14 feet of water. This too was along the north shore of the lake. This was the

first report of this invasive in Crooked Lake (see Figure 18).

Figure 18: Distribution of Curly-Leaf Pondweed and Eurasian Watermilfoil in Crooked Lake 2009

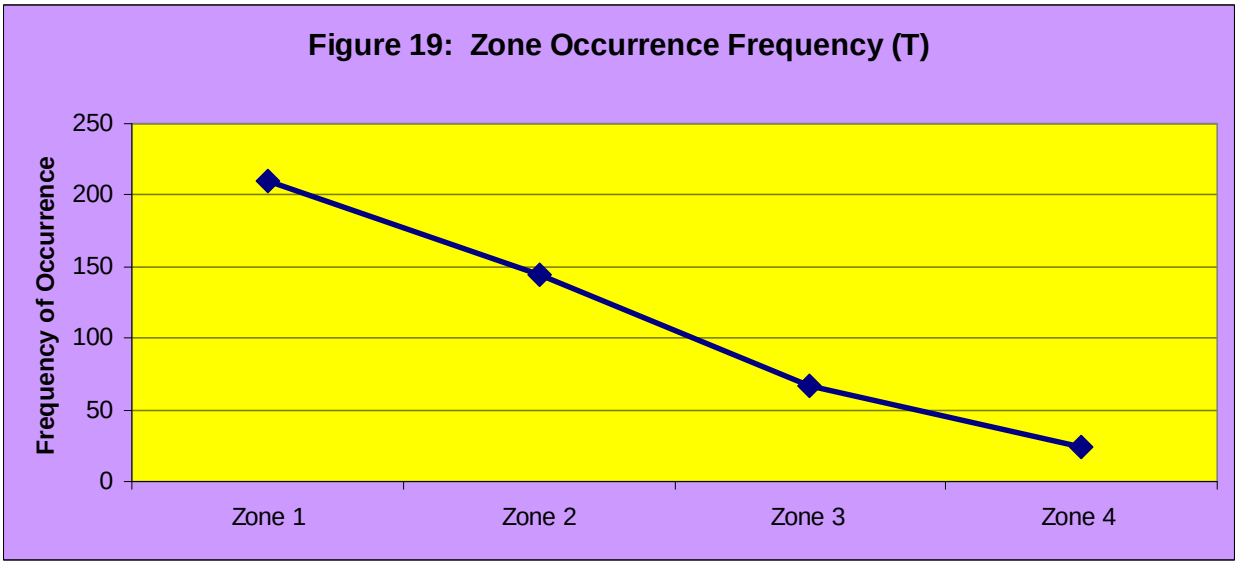
Secchi disc water clarity data can be used to calculate a predicted maximum rooting depth for plants in a lake (Dunst, 1982).

Predicted Rooting Depth (ft.) = (Secchi Disc (ft.) * 1.22) + 2.73

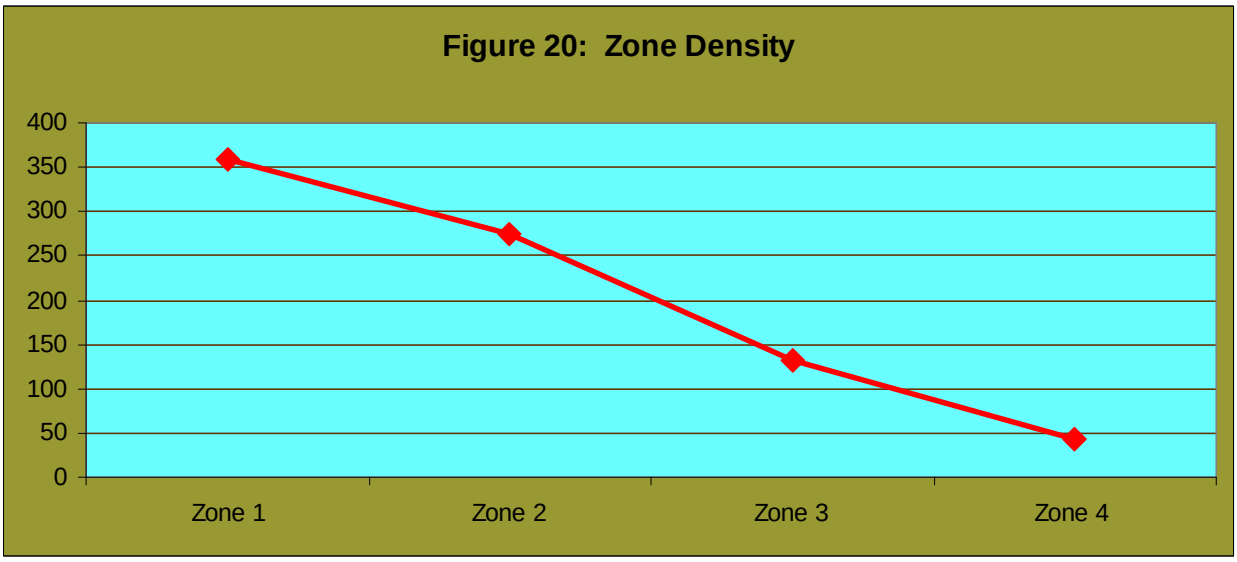
Based on the 2004-2010 average growing season Secchi disc clarity, the predicted maximum rooting depth in Crooked Lake would be 18.2 ft. The actual maximum

rooting depth of 18 feet is roughly equal to the predicted maximum rooting depth based on water clarity. As noted earlier, Crooked Lake has very hard water. Hard water lakes tend to have higher plant growth than soft water lakes. Further, most of Crooked Lake's sediments are types that encourage aquatic plant growth. Finally, Secchi disk readings for water clarity tend to remain more than 10 feet in depth, even in the hottest months of the year. These factors may account for the significant actual rooting depth.

The transect survey resulted showed the greatest frequency of occurrence in Zone 1 (0 to 1.5 feet depth), with less frequency of occurrence as water got deeper.



The same pattern was followed by density, i.e., plants became less dense as the water got deeper (Figure 20).



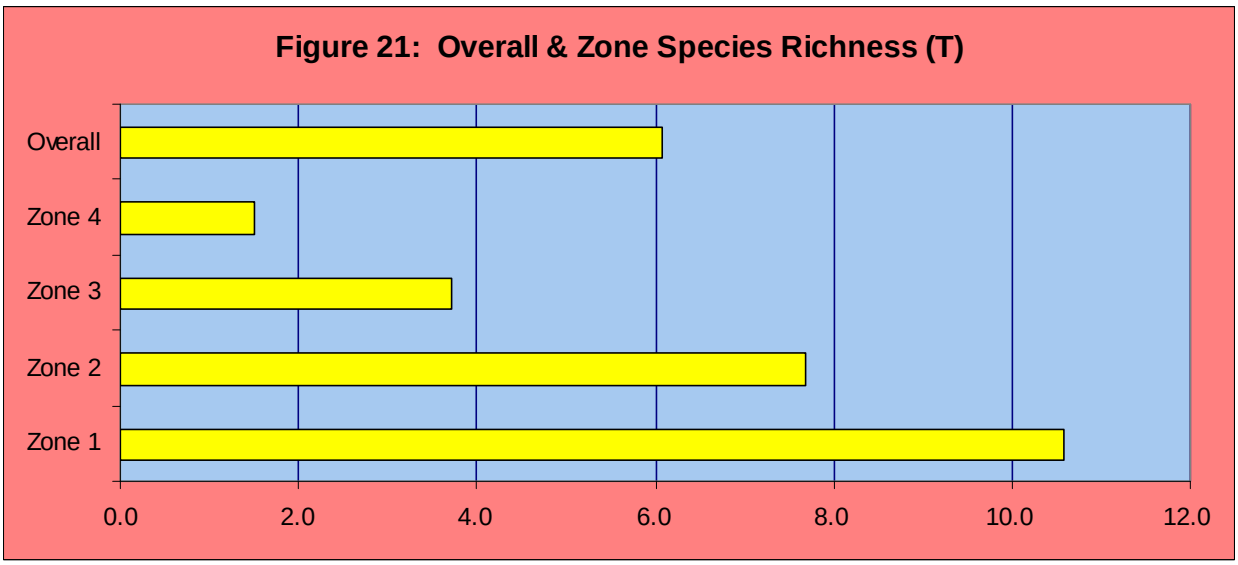
No similar conclusions can be drawn from the PI results, since the data collection method differs and there was only one sample taken in less than 1.5 feet of water and only 21 of 207 samples were taken in less than 5 feet of water depth. In many instances, the greatest diversity of aquatic plants is found in less than 5 feet of water.

THE COMMUNITY

The Simpson's Diversity Index (SI) for the transect 2009 survey was .93 and .85 for the 2009 PI method, dropping to .81 from the 2010 PI reaults. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). All these figures place Crooked Lake in the upper quartile for diversity for all the lakes in Wisconsin and for the North Central Hardwoods Region. The transect SI score of .93 places Crooked Lake in the excellent category for lakes in Wisconsin and in the North Central Hardwoods Region.

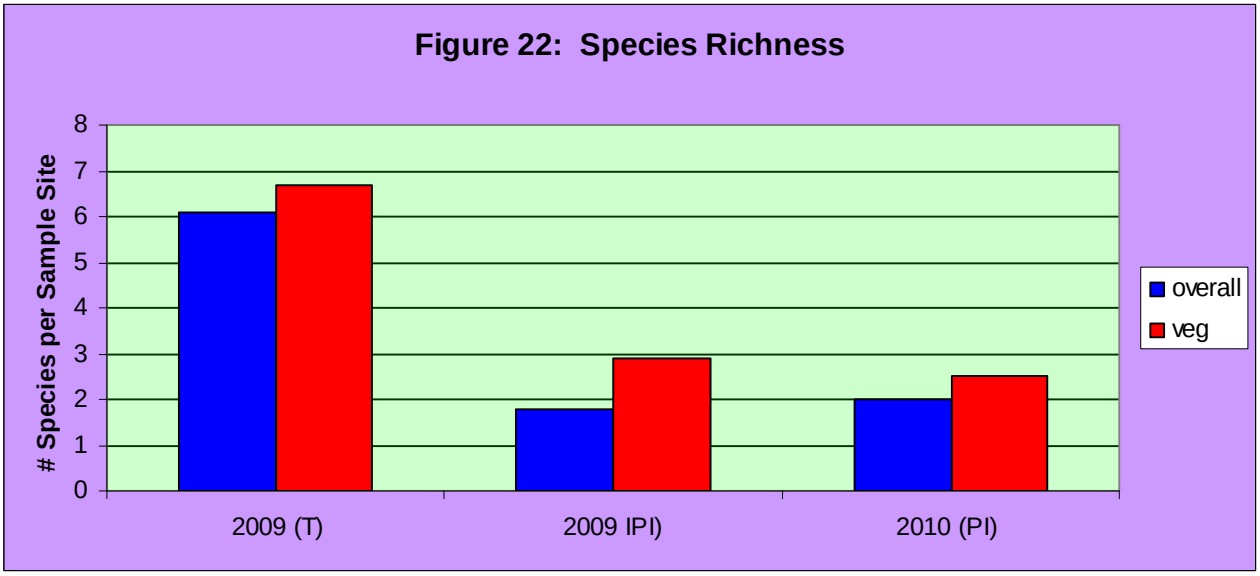
Species richness is the number of species in a given area. When looking at aquatic

survey results, high species richness indicates a higher quality aquatic plant community. The overall 2009 transect species richness (See figure 21) was 6.1. Zone 1 (0-1.5 feet deep) had the highest species richness with 10.6, followed by Zone 2 (1.5-5 feet deep) had a species richness of 7.7. Species richness dropped to 3.7 in Zone 3 (5 to 10 feet deep) and down to 1.5 for Zone 4 (10 to 20 feet deep). .8.



If the species richness was only calculated using richness at vegetated sites, the 2009 Transect overall result increases to 6.7 species per sample site.

Since the PI method doesn't use depth zones for surveying, species richness calculations were done for the 2009 and 2010 results looking at overall species richness (all sample sites) and species richness at vegetated sites only. These results are shown in Figure 22.



The Average Coefficient of Conservation and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance. A coefficient of conservation is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservationism is the mean of the coefficients for the species found in the lake.

The coefficient of conservatism is used to calculate the Floristic Quality Index (FQI), a measure of a plant community's closeness to an undisturbed condition. The Floristic Quality Index is also a tool that can be used to identify areas of high conservation value, monitor sites over time, assess the anthropogenic (human-caused) impacts affecting an area and measure the ecological condition of an area (M. Bourdaghs, 2006).

The Average Coefficient of Conservatism for Crooked Lake was 5.44 for the transect method in 2009. The FQI from the transect method was 39.2. The 5.44 Average

Coefficient of Conservatism places Crooked Lake in the lowest quartile of lakes for Average Coefficient of Conservatism for lakes in Wisconsin overall (see Figure 23). However, the 5.44 score puts Crooked Lake in the mean half of the North Central Hardwoods Region.

The Floristic Quality Index of the aquatic plant community in Crooked Lake was above average for Wisconsin lakes and in the highest quartile of North Central Hardwood Region lakes. The transect FQI score of 39.25 is above the highest quartile for both all Wisconsin lakes and the North Central Hardwood Area This indicates that the plant community in Crooked Lake is closer to an undisturbed condition than the average lake in Wisconsin and within the group of lakes in the region closest to an undisturbed condition.

Results from the 2009 PI survey places Crooked Lake somewhat lower compared to other lakes. The 2009 PI survey Average Coefficient of Conservatism was only 4.79, while the 2009 FQI was 25.32. The 2010 PI survey produced higher results, with an Average Coefficient of Conservatism of 5.89, higher than either 2009 surveys, but a FQI of only 24.98, lower than either of the 2009 survey results.

In general, the FQI results for the PI surveys of Crooked Lake place Crooked Lake in the median range for all Wisconsin lakes and in the upper quartile of North Central Hardwood Lakes. The transect FQI results place Crooked Lake near the top of all Wisconsin lakes and well over any averages for the North Central Hardwood area. The Average Coefficients of Conservatism for all three of these surveys put Crooked Lake in the median range for Wisconsin lakes overall and this geographical area.

Figure 23: Floristic Quality and Coefficient of Conservatism of Crooked Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡
Wisconsin Lakes	5.5, 6.0, 6.9 *	16.9, 22.2, 27.5
NCHR	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4
Crooked Lake 2009-2010	5.44, 4.79, 5.89	39.25, 25.32, 24.98

* - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.
† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).
‡ - lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

Disturbances can be of many types:

1) Physical disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2) Indirect disturbances are the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
3) Biological disturbances include competition from the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by a fish or wildlife population.

The major disturbances in Crooked Lake are likely:

1) the introduction of non-native aquatic plant species;

2) damage by motor boats in the shallow water areas.

Figure 24. Aquatic Macrophyte Community Index, Crooked Lake, 2009-2010

	2009 (t)		2009 (PI)		2009(PI)	
	Value	**Score**	**Value**	**Score**	**Value**	**Score**
Depth of Rooted Plants	5.3 m	10	5.5m	10	4.9m	9
% of Littoral Zone Veg.	90.3	10	87.8	10	74.5	10
% Frequency of Submergent Plants	60	6	73	9	80	10
Taxa Number	52	10	28	10	19	9
% Frequency of Invasive Species	0	10	0	10	0	10
SI score	0.93	10	0.85	6	0.81	5
% Frequency of Sensitive Species	10	7	15	9	25	7
		63		64		60

* The highest value for this index is 70.

The Aquatic Macrophyte Community Index (AMCI) for Crooked Lake (Figure 24) varies from 60 to 64, depending on the particular survey results used. All these values are above average for lakes in the North Central Hardwoods Region and Wisconsin and indicate that the aquatic plant community in Crooked Lake is of above average quality.

COMPARISON TO 2005 RESULTS

In 2005, 24 aquatic species were found in Crooked Lake. In 2009, the transect survey method found 52 species. There were many more emergent species found during the transect survey in 2009, as well as several more submersed species. It is too early to tell whether some of these are transitional species or will stay. Since it's

a natural lake, the water levels of Crooked Lake vary. Also, the diversity of plants in Crooked Lake may be helping to slow the spread of Eurasian Watermilfoil and Curly-Leaf Pondweed.

However, since the 2005 survey, the Adams County Parks Department improved the public boat ramp at Crooked Lake. According to Crooked Lake property owners, the amount of boat traffic into their lake has increased since then. Increased boat traffic can increase the likelihood of the introduction of more invasive species, as well as help spread those already there.

Figure 25	Changes in Aquatic Plant Species (T)				
Species		2005	2009	Year1-2	%
					Change
Aquatic Moss	Frequency	3.23	1.39	-1.84	-57.0%
	Mean Density	0.05	0.01	-0.04	-80.0%
	Dom. Value	0.01	0	-0.01	-100.0%
Asclepias incarnata	Frequency		4.17	4.17	100.0%
	Mean Density		0.06	0.06	100.0%
	Dom. Value		0.01	0.01	100.0%
Aster spp	Frequency		8.33	8.33	100.0%
	Mean Density		0.08	0.08	100.0%
	Dom. Value		0.02	0.02	100.0%
Bidens spp	Frequency		6.94	6.94	100.0%
	Mean Density		0.07	0.07	100.0%
	Dom. Value		0.02	0.02	100.0%
				0	
Brasenia schreberi	Frequency		1.39	1.39	100.0%
	Mean Density		0.04	0.04	100.0%
	Dom. Value		0.01	0.01	100.0%

Carex spp	Frequency	6.45	31.75	25.3	392.2%
	Mean Density	0.11	0.79	0.68	618.2%
	Dom. Value	0.02	0.12	0.1	500.0%
Ceratophyllum demersum	Frequency	9.68	12.5	2.82	29.1%
	Mean Density	0.11	0.18	0.07	63.6%
	Dom. Value	0.03	0.04	0.01	33.3%
Chara spp	Frequency	95.16	90.28	-4.88	-5.1%
	Mean Density	3.53	2.46	-1.07	-30.3%
	Dom. Value	0.53	0.37	-0.16	-30.2%
Cicuta bulbifera	Frequency		0	0	0.0%
	Mean Density		0.01	0.01	100.0%
	Dom. Value		0	0	0.0%
Eleocharis palustris	Frequency	6.45	8.33	1.88	29.1%
	Mean Density	0.11	0.13	0.02	18.2%
	Dom Val	0.02	0.03	0.01	50.0%
Eleocharis quadrangulata	Frequency	1.61	1.39	-0.22	-13.7%
	Mean Density	0.06	0.03	-0.03	-50.0%
	Dom Val	0.01	0	-0.01	-100.0%
Elodea canadensis	Frequency		6.94	6.94	100.0%
	Mean Density		0.11	0.11	100.0%
	Dom Val		0.02	0.02	100.0%
Eupatorium perfiolatum	Frequency		4.17	4.17	100.0%
	Mean Density		0.01	0.01	100.0%
	Dom Val		0.01	0.01	100.0%
Eupatorium purpurea	Frequency		6.94	6.94	100.0%
	Mean Density		0	0	100.0%
	Dom Val		0.02	0.02	100.0%
Iris versicolor	Frequency		1.39	1.39	100.0%
	Mean Density		0.01	0.01	100.0%
	Dom Val		0	0	100.0%
Juncus spp	Frequency		6.94	6.94	100.0%
	Mean Density		0.1	0.1	100.0%

	Dom Val		0.02	0.02	100.0%
Lemna minor	Frequency	3.23	4.17	0.94	29.1%
	Mean Density	0.06	0.07	0.01	16.7%
	Dom Val	0.01	0.01	0	0.0%
Lobelia kalmii	Frequency		5.56	5.56	100.0%
	Mean Density		0.08	0.08	100.0%
	Dom Val		0.01	0.01	100.0%
Myriophyllum heterophyllum	Frequency	16.13	20.83	4.7	29.1%
	Mean Density	0.19	0.38	0.19	100.0%
	Dom Val	0.05	0.07	0.02	40.0%
Myriophyllum sibircum	Frequency	45.16	52.78	7.62	16.9%
	Mean Density	0.79	0.96	0.17	21.5%
	Dom Val	0.17	0.17	0	0.0%
Myriophyllum spicatum	Frequency	1.61	4.17	2.56	159.0%
	Mean Density	0.02	0.04	0.02	100.0%
	Dom Val	0	0.01	0.01	100.0%
Najas flexilis	Frequency	14.52	15.28	0.76	5.2%
	Mean Density	0.31	0.21	-0.1	-32.3%
	Dom Val	0.06	0.04	-0.02	-33.3%
Nuphar variegata	Frequency	22.58	16.67	-5.91	-26.2%
	Mean Density	0.58	0.35	-0.23	-39.7%
	Dom Val	0.1	0.06	-0.04	-40.0%
Nymphaea odorata	Frequency	62.9	52.78	-10.12	-16.1%
	Mean Density	1.82	1.38	-0.44	-24.2%
	Dom Val	0.3	0.21	-0.09	-30.0%
Onoclea sensibilis	Frequency		1.39	1.39	100.0%
	Mean Density		0.01	0.01	100.0%
	Dom Val		0	0	0.0%
Pedicularis lanceolata	Frequency		2.78	2.78	100.0%
	Mean Density		0.03	0.03	100.0%
	Dom Val		0.01	0.01	100.0%

Phalaris arundinacea	Frequency		2.78	2.78	100.0%
	Mean Density		0.03	0.03	100.0%
	Dom Val		0.01	0.01	100.0%
Polygonum amphibium	Frequency		4.17	4.17	100.0%
	Mean Density		0.04	0.04	100.0%
	Dom Val		0.01	0.01	100.0%
Potamogeton foliosus	Frequency		4.17	4.17	100.0%
	Mean Density		0.04	0.04	100.0%
	Dom Val		0.01	0.01	100.0%
Potamogeton gramineus	Frequency	1.61	5.56	3.95	245.3%
	Mean Density	0.02	0.08	0.06	300.0%
	Dom Val	0	0.02	0.02	100.0%
Potamogeton illinoiensis	Frequency	4.84	1.39	-3.45	-71.3%
	Mean Density	0.05	0.01	-0.04	-80.0%
	Dom Val	0.01	0	-0.01	-100.0%
Potamogeton natans	Frequency	29.03	20.83	-8.2	-28.2%
	Mean Density	0.44	0.38	-0.06	-13.6%
	Dom Val	0.1	0.06	-0.04	-40.0%
Stuckenia pectinata	Frequency	19.35	30.56	11.21	57.9%
	Mean Density	0.23	0.36	0.13	56.5%
	Dom Val	0.06	0.08	0.02	33.3%
Potamogeton praelongus	Frequency		1.39	1.39	100.0%
	Mean Density		0.01	0.01	100.0%
	Dom Val		0	0	0.0%
Potmogeton zosteriformis	Frequency	22.58	16.67	-5.91	-26.2%
	Mean Density	0.37	0.26	-0.11	-29.7%
	Dom Val	0.08	.05	-0.03	-37.5%
Rumex orbiculatus	Frequency		1.39	1.39	100.0%
	Mean Density		0.01	0.01	100.0%
	Dom Val		0	0	0.0%
Sagittaria spp	Frequency	1.61	1.39	-0.22	-13.7%
	Mean Density	0.02	0.04	0.02	100.0%

	Dom Val	0	0.01	0.01	100.0%
Scirpus validus	Frequency	30.65	29.17	-1.48	-4.8%
	Mean Density	0.82	0.68	-0.14	-17.1%
	Dom Val	0.14	0.11	-0.03	-21.4%
Solidago canadensis	Frequency		5.56	5.56	100.0%
	Mean Density		0.07	0.07	100.0%
	Dom Val		0.02	0.02	100.0%
Spiranthes romanzoffiana	Frequency		1.39	1.39	100.0%
	Mean Density		0.01	0.01	100.0%
	Dom Val		0.01	0.01	100.0%
Spirodela polyrhiza	Frequency	3.23	2.78	-0.45	-16.2%
	Mean Density	0.05	0.06	0.01	16.7%
	Dom Val	0.01	0.01	0	0.0%
Typha spp	Frequency	6.45	18.06	11.61	64.3%
	Mean Density	0.11	0.42	0.31	73.8%
	Dom Val	0.02	0.07	0.05	71.4%
Utricularia gemniscapa	Frequency	9.68	12.5	2.82	22.6%
	Mean Density	0.1	0.15	0.05	33.3%
	Dom Val	0.03	0.03	0	0.0%
Utricularia gibba	Frequency	1.61	11.11	9.5	85.5%
	Mean Density	0.02	0.11	0.09	81.8%
	Dom Val	0	0.03	0.03	100.0%
Utricularia intermedia	Frequency		2.78	2.78	100.0%
	Mean Density		0.03	0.03	100.0%
	Dom Val		0.01	0.01	100.0%
Utricularia minor	Frequency		2.78	2.78	100.0%
	Mean Density		0.03	0.03	100.0%
	Dom Val		0.01	0.01	100.0%
Utricularia vulgaris	Frequency	38.71	45.83	7.12	18.4%
	Mean Density	0.69	0.67	-0.02	-2.9%
	Dom Val	0.15	0.14	-0.01	-6.7%

Wolffia columbiana	Frequency		5.56	5.56	100.0%
	Mean Density		0.07	0.07	100.0%
	Dom Val		0.02	0.02	100.0%

The plant communities were compared by calculating coefficients of similarity, using both actual frequency of occurrence and relative frequency of occurrence. Based on actual frequency of occurrence for the two transect methods, the 2005 and 2009 aquatic plant communities were 79.19% similar. Based on relative frequency, they were 93.75% similar. Coefficients of similarity over 75% suggest that the plant community is substantially the same, despite the difference in numbers of species.

New plants found in 2009 that were not found in 2005 are: *Asclepias incarnata; Asters* spp; *Bidens* spp; *Brasenia schreberi; Cicuta bulbifera; Elodea Canadensis; Eupatorium perfiolatum; Eupatorium purpurea; Iris versicolor; Juncus* spp.; *Lobelia kalmii; Najas guaelupensis; Onocela sensibilis; Pedicuaris lanceolata; Polygonum amphibium; Potamogton crispus; Potamogeton foliosis; Potamogeton freisii; Poamogeton nodusus; Potamogeton praelongus; Rumex orbiculatus; Salix; Solidago canadensis; Sparganium emersum; Scirpus acutus; Spiranthes romanzoffiana; Untricularia intermedia; Utricularia minor* and *Wolffia columbiana.* There were no plants in 2005 that weren't also found in 2009 in one or both surveys.

Figure 26: Changes in Aquatic Plant Community (transect)

Crooked 2009--transects	2005	2009	Change	%Change
Number of Species	25	51	26	104.0%
Maximum Rooting Depth	19.0	17.5	-2	-7.9%
% of Littoral Zone Unvegetated	0	9.7	9.7	100.0%

%Sites/Emergents	22.56%	34.72%	0.1	53.9%
%Sites/Free-floating	3.23%	4.17%	0.0	29.1%
%Sites/Submergents	95.16%	90.30%	0.0	-5.1%
%Sites/Floating-leaf	61.02%	75.00%	0.1	22.9%
Simpson's Diversity Index	0.91	0.93	0.02	2.2%
Species Richness	4.58	6.10	1.52	33.2%
Floristic Quality	26.44	39.25	12.81	48.4%
Average Coefficient of Conservatism	5.64	5.44	-0.20	-3.5%
AMCI Index	54	63	9.00	16.7%

Transect survey results can't be compared the same way to PI results, but calculations were done comparing the 2009 and 2010 PI results.

Figure 27: Comparisons between 2009 and 2010 PI surveys

Crooked 2009-2010	2009PI	2010(PI)	Change	%Change
Number of Species	28	19	-9.00	-32.1%
Maximum Rooting Depth	15.0	16.0	1.00	6.7%
% of Littoral Zone Unvegetated	37.2	25.5	-11.70	-31.5%
%Sites/Emergents	2.9	4.3	1.40	48.3%
%Sites/Free-floating	2.4	0.7	-1.70	-70.8%
%Sites/Submergents	54.1	66.0	11.90	22.0%
%Sites/Floating-leaf	21.7	24.8	3.10	14.3%
Simpson's Diversity Index	0.85	0.81	-0.04	-4.7%
Species Richness	2.91	1.89	-1.02	-35.1%
Floristic Quality	25.32	24.98	-0.34	-1.3%
Average Coefficient of Conservatism	4.79	5.89	1.10	23.0%
AMCI Index	64	60	-4.00	-6.3%

Considerably fewer aquatic plants were found during the 2010 PI survey than the 2009 survey. In particular, the following plants were found in 2009, but not in 2010: *Elodea canadensis; Potamogeton crispus; Potamogeton foliosus; Sagittaria spp; Sparganium eurycarpum; Spirodela polyrhiza;* and *Utricularia minor.* There were also two species found in 2010 that weren't found in 2009: *Nitella spp;* and

Utricularia gibba.

The PI plant communities from 2009 and 2010 were also compared using relative frequency and actual frequency of occurrence. If the two communities share a coefficient of conservatism over 75%, they are considered statistically similar. On actual frequency of occurrence, the 2009 and 2010 PI results were 89.4% similar. Using relative frequency, they were 81.5% similar. Thus, although some species varied, the two communities are statistically similar.

V. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Crooked Lake is a borderline oligotrophic/mesotrophic lake with good-to-very good water clarity and water quality. Filamentous algae were most common at depths greater than 5 feet.

Adequate nutrients (including sediments), good water clarity, hard water, the large shallow areas in the lake and the gradually sloped littoral zone in Crooked Lake would favor plant growth.

Aquatic plants occurred throughout the entire littoral zone (under 20 feet deep). *Myriophylum sibiricum* and *Potamogeton zosteriformis* were the deepest-occuring rooted aquatic plants. *Chara* spp. was found in depths up to 23 feet, but it is not a rooted plant. The highest total occurrence of plants, highest total density of plants and the greatest species richness occurred in the 0-1.5ft depth zone.

Fifty-eight (58) species of aquatic plants were recorded in Crooked Lake in 2009.

As it was in 2005, *Chara* spp. was the dominant plant species in Crooked Lake in 2009. It dominated all depth zones, was found at over 90% of sample sites, grew in water up to 23 feet deep and exhibited a dense form of growth in Crooked Lake. *Nymphaea odorata* was sub-dominant and also grew at above average densities.

The endangered species, *Eleocharis quadrangulata*, is still confined to one patch found along the south shore of the lake. *Utricularia geminiscapa*, a species of special concern in Wisconsin, was found in all four depth zones, but was scattered and sparse. Only *Chara* spp exhibited greater than average growth density. The dominant and common species were found throughout the lake. Species found commonly or abundantly in Crooked Lake in either 2009 survey included: *Carex* spp; *Chara* spp.; *Myriophyllum heterophyllum; Myriophyllum sibiricum; Nymphaea odorata; Potamogeton nodosus; Stuckenia pectinata; Potamogeton zosteriformis; Scirpus valids;* and *Utricularia vulgaris.*

Eurasian watermilfoil was found at in 4 places in 2009. All locations were along the northeast shore of the lake, near the boat ramp where it was discovered in 2005. No EWM was found during the 2010 survey. Eurasian watermilfoil had a low frequency and low density in 2005, but there is no question that it has spread since being found in 2005, since 3 of the 4 2009 locations were some distance east of the two spots where EWM was found in 2005. It remains at low density when found. The Crooked Lake Association intends to continue to monitor it regularly, with help from the Adams County Land & Water Conservation Department. The lake association also will continue its “pulling parties” with hand removal of Eurasian watermilfoil. It has gotten quotes from chemical applicators in case a rapid response for chemical treatment is necessary because of an increase in the occurrence and/or density of

Eurasian watermilfoil. The Crooked Lake Association will likely apply for a WDNR grant if it is determined that chemical treatment is required to control the invasive.

The Crooked Lake Association will also start monitoring Curly-Leaf Pondweed, which was found during the PI survey in 2009 at one sample site (although not found in 2010). This site is one at which Eurasian watermilfoil was also found in 2009 and is very close to the public boat ramp, suggesting that it—like the earlier-found Eurasian watermilfoil—entered the lake through boat traffic.

The Aquatic Macrophyte Community Index (AMCI) for Crooked Lake was 63 (transect method), indicating that the quality of the plant community in Crooked Lake is above average for lakes in Wisconsin and the region. The transect Simpson's Diversity Index (0.93) indicates that the aquatic plant community had an excellent diversity of plant species.

The Average Coefficient of Conservatism and the Floristic Quality Index indicate that Crooked Lake has an above average sensitivity to disturbance and is in the upper quartile of lakes (top 25%) in the North Central Hardwood Region, the group of lakes in the region closest to an undisturbed condition. When compared to lakes over the whole state, Crooked Lake remains above average, closer to an undisturbed condition than the average lake. Damage by motor boats in the shallow areas and the introduction of Eurasian Watermilfoil and Curly-Leaf Pondweed are likely the biggest disturbance in Crooked Lake.

Shoreline Impacts

Shorelines with cultivated lawn can impact the plant community through increased

run-off of lawn fertilizers, pesticides and pet wastes into the lake and also speed run-off to the lake without filtering these pollutants. Protecting the buffer of natural vegetation around Crooked Lake will help prevent shoreline erosion and reduce additional nutrient/chemical run-off that can add to algae growth and sedimentation of the lake bottom.

To determine if there was a difference in the aquatic plant community at the sites with lawn, the aquatic plant transect sites off sites with 100% natural shoreline were compared to aquatic plant transect sites off shoreline that contained any amount lawn or other disturbance (see Figure 28).

The comparison of various parameters indicate that disturbance on the shore has impacted the aquatic plant community at those sites. All of the methods discussed earlier for evaluating the quality of the aquatic plant community were higher at the undisturbed shores than at the few shorts with disturbance.

Figure 28: Disturbed v. Undisturbed Shore Site Indices (T)

	Disturbed	Natural
# species	33	48
Average Coef.	5.42	5.52
FQI	31.16	38.25
Simpson's Index	0.93	0.94
AMCI	60	61
Species Richness (# species/sample site)	6.04	6.75

Even the numbers for the disturbed shore are higher than state averages. The amount of disturbance at 2/3 of the disturbed sites was less than 15%. Overall, disturbed sites cover only about 9% of the shore. This might account for the relatively high

level of the aquatic plant community even at the disturbed shores in Crooked Lake. However, that there is a difference in so many indices, even with such a small amount of disturbance, suggests that an increase in disturbed shores at Crooked Lake is likely to result in a lower-quality aquatic plant community.

V. CONCLUSIONS

Crooked Lake is a mesotrophic/oligotrophic lake with good-to-very good water quality and clarity. The aquatic plant community colonized 90% of the littoral zone of the lake and 62% of the lake overall. The 0-1.5feet depth zone supported the most abundant aquatic plant growth. The 1.5 feet to 5 feet depth zone also had abundant plant growth. Plant growth drops off substantially after 5 feet, although rooted aquatic plants were found as deep as 18 feet (*Myriophyllum sibiricum* and *Potamogeton zosteriformis*) and macrophytic algae, *Chara* spp., was found in 21 feet of water.

Chara spp. was the dominant species found in both of the aquatic plant surveys in 2009, dominating all depth zones and exhibiting a dense form of growth. *Chara* spp. was the only member of the aquatic plant community that occurred at more than average density of growth. *Nymphaea* odorat, which was sub-dominant in the under 5 feet depth zones, did not exhibit a growth form of above average density. The most common species were found distributed throughout the lake's littoral zone.

An endangered species was found in Crooked Lake, *Eleocharis quadrangluata.* One species of special concern, *Utricularia gemniscapa*, was also found in Crooked Lake

in 2009. Both of these species were also found during the 2005 aquatic plant survey. A number of other high-quality sensitive aquatic plants were also found: *Aster linearifolius; Lobelia kalmii; Najas guadelupensis; Pedicularis lanceolata; Potamogeon friesii; Rumex orbiculatus; Sparganium emersum; Spiranthes romanzoffiana; Utricularia gibba; Utricularia intermedia;* and *Utricularia minor.*

Three invasive aquatic plant species were found in the 2009 surveys. Two of them—*Myriophyllum spicatum* and *Phalaris arundinacea*—were found during the first aquatic plant survey done in 2005. However, another invasive—*Potamogeton crispus*—was found for the first time during 2009. Both Eurasian Watermifoil and Curly-Leaf Pondweed were found only near the boat landing or directly right or left of the boat landing. These plants occurred at low density and low frequency, but considering the aggressiveness with which they usually spread once they've entered a lake, their presence is an issue of concern, even though they weren't found during the 2010 survey.

The Crooked Lake aquatic plant community is characterized by above average quality and very good species diversity. The plant community is in the top quartile of lakes in the region, the group of lakes closest to an undisturbed condition and with an above average tolerance to disturbance. Its high quality aquatic plant community may contribute to the relative containment of the invasives so far.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in: 1) improving water quality; 2) providing valuable habitat resources for fish and wildlife; 3) resisting invasions of non-native species; and 4) checking excessive growth of tolerant species that could crowd out

the more sensitive species, thus reducing diversity. Aquatic plant communities improve water quality in many ways (Engel 1985):

- they trap nutrients, debris, and pollutants entering a water body;
- they absorb and break down some pollutants;
- they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
- they remove nutrients that would otherwise be available for algae blooms.

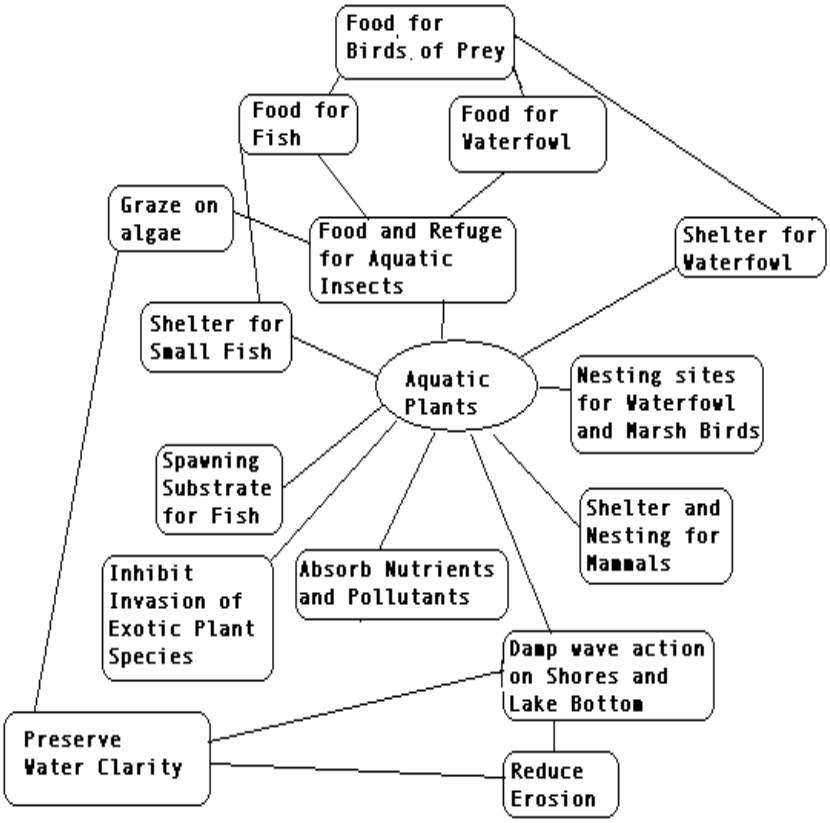


Figure 29: Aquatic Ecological Web

Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish and are an essential part of the ecological web of a lake (Figure 29). Plant cover within the littoral zone of

Crooked Lake is 90% and over the whole lake is 82.5% and seems appropriate to support a balanced fishery.

Lakes with diverse aquatic plant beds support larger, more diverse invertebrate populations that in turn support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of aquatic plants support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Aquatic plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).

MANAGEMENT RECOMMENDATIONS

1) All lake residents should practice best management on their lake properties. Crooked Lake is borderline between oligotrophic and mesotrophic. A small increase in nutrients could push the lake into another trophic state, resulting in noticeably worse water quality. Conversely, reducing nutrients could have a noticeable favorable impact on water quality.

- Keep septic systems cleaned and in proper condition;
- Use no lawn fertilizers;
- Clean up pet wastes;
- No composting should be done near the water nor should yard wastes & clippings be allowed to enter the lake (Do not compost near the water or allow yard wastes and clippings to enter the lake).

2) Residents should continue involvement in the Citizen Lake Monitoring Program, monitoring water quality to track seasonal and year-to-year changes.

3) Now that most of the lake is designated as critical habitat areas, a map of these areas should be posted at the public boat ramp with a sign encouraging avoidance of motorboat disturbance to these areas. Landowners on the lake should watch for disturbance of these areas and report any violations. These areas are very important for habitat, the high value aquatic plant community, maintaining the positive water quality and for preserving endangered and rare species.

4) The Crooked Lake Association should continue working with the Adams County Land & Water Conservation Department in the ongoing Eurasian Watermilfoil removal project and also start hand-removing Curly-Leaf Pondweed. These exotic species should be controlled and maybe eliminated before it spreads. Initially, hand-pulling could be attempted. However, considering the shallow areas of Crooked Lake are several feet deep in marl muck, spot chemical treatments may be required for control in these areas.

5) A harvesting and/or herbicide map must be developed to identify the corridors to be cleared for boating access around the lake.

6) Lake residents should protect natural shoreline around Crooked Lake. Cultivated lawn covers 6% of the shore. In most instances on Crooked Lake, there are already buffer areas even at the disturbed sites. An increase in the depth of these buffer areas is recommended to 35 feet landward from shore.

7) Steps should be taken to regulate boat speed in the shallow water areas to

reduce disturbance to plant.

8) All lake users should protect the aquatic plant community in Crooked Lake. The standing-water emergent community, floating-leaf community and submergent plant community are all unique plant communities. Each of these plant communities provides their own benefits for fish and wildlife habitat and water quality protection.

9) An aquatic plant survey should be repeated in 3 to 5 years in order to continue to track any changes in the community and the lake's overall health.

10) The Crooked Lake Association should consider approaching the two landowners who own much of the waterfront property on the east and west sides of the lake and see if those landowners would be interested in conservation easements. If so, the Crooked Lake Association could apply for a WDNR grant to gain these easements. These easements would help ensure that the threatened habitats on Crooked Lake remain undisturbed.

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